ELECTRICAL TABLES AND FORMULÆ.

ELECTRICAL

TABLES AND FORMULÆ

FOR THE USE OF

TELEGRAPH INSPECTORS AND

OPERATORS.

COMPILED BY

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PREFACE.

THE Appendix to a small work on "Electrical Measurements,"* by one of the Authors, containing many electrical data and formulæ, having proved useful, and met with approval amongst telegraphists, they have been induced to undertake the following more complete compilation, which they believe will supply an admitted want.

In bringing together such a heterogeneous mass of materials it has been found difficult to follow consistently any systematic plan of arrangement; but it is hoped that a tolerably copious index will render this unavoidable absence of system a matter of small importance.

In the following pages, the "*specific resistance*" of any insulator has been assumed to be the resistance of a cube knot of the material, at 75° F., calculated from its measured resistance in the form of a cable. In the same way, its "*specific electro-static capacity*" is taken as the

* "An Elementary Treatise on Electrical Measurements," &c., by Latimer Clark. E. & F. N. Spon, Charing Cross, 1868.

capacity of a cube knot reduced from the measured capacity of a cable. The reason why the authors have adopted these definitions is because, the knot being the accepted unit of length in cable work, it saves, when thus employed, the introduction of numerical constants in some of the formulæ, and at the same time affords convenient values in megohms and microfarads respectively. The resistance of a cube knot is the same as that of a strip of the material whose thickness (in the direction of the current) is the same as its breadth, and whose extent of surface, the other way, is one knot.

The word *mil* has been retained as representing the thousandth part of an inch, which in electrical work is found to be a unit of measure of constant practical application.

The names *farad*, *ohm*, and *volt*, have not been formally sanctioned by the Committee appointed to report on units by the British Association; they have, however, come into hourly use among the members of the Committee, and among electricians at large; and are doubtless destined to be adopted universally. It may be mentioned that, by common consent, the value at first assigned to the *farad*, as expressing the unit of capacity, has now been assigned to the *microfarad:* this was done to preserve the unity and simplicity of the system. The word *veber* has also been introduced to express the unit quantity of electricity, or that which

passes through one *ohm*, in one *second*, with a difference of tension of one *volt*.

The Authors have made free use of every source of information which was available to them, and have to acknowledge the ready assistance and co-operation they have received at all hands. Their thanks are particularly due to Sir Charles Wheatstone, Mr. G. Preece, Mr. Willoughby Smith, Mr. Charles Hockin, Mr. Herbert Taylor, Mr. Bruce Warren, and Mr. H. C. Forde, for useful contributions: they are also indebted to the works and writings of Sir W. Thomson, Mr. C. W. Siemens, Messrs. Brook and Longridge, Mr. Fleeming Jenkin, and many others whom it is needless to particularize.

ELECTRICAL

TABLES AND FORMULÆ.

Formulæ of the absolute system of Units.

1. *Fundamental units.*

Length or space = L. Time = T. Mass = M.

2. *Derived Mechanical Units.*

$$\text{Work} = W = \frac{L^2 M}{T^2}.$$

$$\text{Force} = F = \frac{L M}{T^2}.$$

$$\text{Velocity} = V = \frac{L}{T}.$$

3. *Derived Magnetical Units.*

Strength of the pole of a magnet . . $m = L^{\frac{3}{2}} T^{-1} M^{\frac{1}{2}}$.

Moment of a magnet . . . . . . $ml = L^{\frac{5}{2}} T^{-1} M^{\frac{1}{2}}$.

Intensity of a magnetic field . $H = L^{-\frac{1}{2}} T^{-1} M^{\frac{1}{2}}$.

4. *Electro-magnetic system of Units.*

Quantity of Electricity . . . $Q = L^{\frac{1}{2}} \times M^{\frac{1}{2}}$.

Strength of Electric Current . $C = L^{\frac{1}{2}} T^{-1} M^{\frac{1}{2}}$.

Electro-motive force . . . . $E = L^{\frac{3}{2}} T^{-2} M^{\frac{1}{2}}$.

Resistance of conductor . . $R = L T^{-1}$.

5. *Electro-static system of Units.*

Quantity of electricity . . .	$q = L^{\frac{3}{2}}\ T^{-1}\ M^{\frac{1}{2}} = v\,Q.$
Strength of electric currents .	$c = L^{\frac{3}{2}}\ T^{-2}\ M^{\frac{1}{2}} = v\,C.$
Electro-motive force . . .	$e = L^{\frac{1}{2}}\ T^{-1}\ M^{\frac{1}{2}} = \frac{E}{v}.$
Resistance of conductor . .	$r = L^{-1}\ T\ .\ .\ = \frac{R}{v^2}.$

Note.—$v = 310,740,000$ metres, per second approximately; the ratio of the electro-static to the electro-magnetic unit of quantity.

Force, Work, and Performance.

The unit of force in the system of absolute measures is defined to be that force which would produce in a body weighing one gramme a velocity of one metre per second. Now gravitation, acting upon a freely falling body, accelerates it 9·81 metres per second. Therefore, calling the natural unit of force the terrestrial acceleration of one gramme, it is evident that the absolute unit of force will be only the $\frac{1}{9{\cdot}81}$th part of it, or $\frac{1}{9{\cdot}81}$ of a gramme, acted upon by the earth's attraction, or simply the weight of $\frac{1}{9{\cdot}81}$ gramme.

The unit of work or mechanical effect is the unit of force carried up through one metre; it is therefore equal to $\frac{1}{9{\cdot}81}$ gramme raised one metre high.

The unit of mechanical performance may, in the same way, be defined as the unit of work performed in the unit of time, or $\frac{1}{9{\cdot}81}$ gramme raised one metre, in one second.

Electrical Units of Measurement.

The B. A. units are becoming generally adopted in England and elsewhere, and we confine our measurements to them, as being the most rational and concordant.

1. *Resistance.*—The B. A. resistance unit is called an *ohm.* It is equal to the resistance of a prism of pure mercury 1 square millimetre section and 1·0486 metres long, at 0° cent.

One *ohm* is equal to 10^7, or 10,000,000 absolute electro-magnetic units.

A *megohm*—the unit of resistance used in expressing insulations—is equal to a million *ohms.* A *megohm* is therefore equal to 10^{13} absolute electro-magnetic units of resistance.

A *microhm* is the smallest resistance unit, being equal to one-millionth part of an *ohm,* or to 10 absolute electro-magnetic units.

2. *Electro-motive force.*—The B. A. unit of tension or difference of potentials is called a *volt,* which is rather *less* than the electro-motive force of a Daniell's element.

One *volt* equals 10^5 absolute electro-magnetic units of electro-motive force, and, according to Professor Thomson's determination, is about equivalent to 0·9268 times the electro-motive force of a Daniell's element.

A *megavolt* = one million volts.

A *microvolt* = one millionth of a volt, or to $\frac{1}{10}$ of an absolute unit.

3. *Current.*—The B. A. unit of current is equivalent to *one veber per second;* or the current in a circuit having

an electro-motive force of one volt and a resistance of one ohm.

4. *Quantity.*—The B. A. unit of quantity is called a *veber*,* and represents that quantity of electricity which flows through a circuit having an electro-motive force of one *volt* and a resistance of one *ohm*, in one second. It is equal to $\frac{10^5}{10^7}$ or $\frac{1}{100}$th of an absolute unit of quantity.

A *megaveber* is equal to one million *vebers*.

A *microveber* is one millionth of a veber or $\frac{10^5}{10^{13}}$ absolute electro-magnetic units of quantity.

5. The B. A. unit of capacity is called a *farad*,* and is equal to 10^{-7} absolute units of capacity. The *capacity* of any electrified body is that *quantity* of electricity which it contains when the inductive surfaces have a difference of potential of one *volt*.

A *megafarad* is a million *farads*.

A *microfarad* is the millionth part of a farad.

The electro-static capacity of submarine telegraph cables, per knot length, averages $\frac{1}{3}$ of a *microfarad*.

The electro-static capacity of the whole Atlantic Cable is less than 800 microfarads.

6. *Heat.*—The *unit of heat* is the quantity of heat required to raise one gramme of water one degree (Cent.) of temperature.

According to Joule a unit of heat is equivalent to raising 423·5 grammes weight, one metre high. Therefore

* See *Preface*.

1 unit of heat = $423.5 \times 9.81 = 4155$ absolute units of work.

7. *Electro-Chemical equivalent.*—One *veber* of electricity decomposes 0·00142 grains of water or develops 0·0105 cubic inches of mixed gas, at a temperature of 0° C. and barometer pressure of 760 $^{m}/_{m}$.

In a circuit through which a quantity of one *veber* passes, per second (or which has an electro-motive force of one *volt* and a resistance of one *ohm*), the weight of hydrogen gas developed, per second, is 0·000158 grains.

Therefore the weight of any metal reduced by the unit of current, per second, is

$$0.000158 \times \text{its atomic weight.}$$

If a be the atomic weight of any metal in a salt submitted to electrolysis; R the resistance of the circuit in ohms; and E the electro-motive force in volts; the weight of metal reduced in t seconds will be

$$0.000158 \frac{a\,E\,t}{R} \text{ (grains).}$$

Various Units of Electrical Resistance.

1. *Wheatstone's unit.** — To Professor Sir Charles Wheatstone is due the credit of having constructed (in 1840) the first instruments by which definite multiples of a resistance unit could at will be added to or subtracted from a given circuit. The standard resistance unit which he proposed and employed was that of 1 foot of copper wire, weighing 100 grains.

2. *Jacobi's units.*—Professor Jacobi of St. Petersburg

* "Phil. Trans.," 1843, vol. cxxxiii., p. 303.

has made various suggestions for units of electrical resistance. The unit which is commonly known as Jacobi's unit, and of which he sent copies to various physicists, was made of a length of 25 feet of a certain copper wire, weighing 345 grains.

Another proposition of Professor Jacobi was to employ as unit of electrical resistance that of a copper wire 1 metre long and 1 millimetre diameter.

3. *Siemens' mercury unit.*—This unit represents, according to the definition of Dr. Werner Siemens, the resistance of a prism of pure mercury 1 metre long and 1 square millimetre section, at 0° C.

This unit was first produced in 1860, and resistance coils in German silver wire were adjusted from it. A reproduction of the normal resistance tubes, in 1863, was found to agree within 0·1 per cent. with the results originally obtained. An error, arising from the specific gravity of mercury having been taken as 13·557 instead of 13·596, was corrected in 1866; so that all Siemens' resistance coils issued previously to that date are 0·29 per cent. too great. That is to say, the resistances which are marked as 1 are really 1·0029 mercury units, and the end results have to be multiplied by this constant (1·0029) in order to be expressed in mercury units according to the definition. One Siemens' unit = 0·9536 ohms.

4. *French and Swiss units.*—In the telegraph administrations of France and Switzerland the unit of the electrical resistance coils in use for some time prior to 1867 was equivalent to the resistance of a length of one kilometre of the iron wire employed for the telegraph lines, 4

millimetres diameter. As no very exact measurements are required to be made of overhead lines, these units were not either defined or produced very exactly, and no temperature was given to enable a reproduction of the units if it should have been deemed desirable. Consequently the unit coils of the Swiss ateliers, and those of Bréguet and Digney, differed amongst themselves as much as 15 per cent. In 1867 both Bréguet and Digney readjusted their units to $\frac{1}{10}$ of a mercury unit, which is very nearly their original value. In all French submarine cable work, resistance coils adjusted to the mercury unit are employed.

5. *Matthiessen's unit.*—This unit was defined as the resistance of a statute mile of pure annealed copper wire $\frac{1}{16}$ of an inch diameter, at 15·5° C.

6. *Varley's unit.* — This unit obtained considerable employment in cable and line work of the E. and I. Telegraph Company. Mr. Varley originally constructed it from a statute mile of special copper wire $\frac{1}{16}$ of an inch diameter; but afterwards readjusted it to 25 mercury units.

7. *German-mile unit.*—The first unit of measurement used in the telegraph service in Berlin was that of a German mile (= 8238 yards) of copper wire, its diameter being $\frac{1}{12}$ of an inch, and its temperature 20° Cent. Resistances adjusted to this unit were manufactured as early as 1848 by Messrs. Siemens and Co., but have been long since superseded in Prussia, by coils adjusted to the mercury unit.

Relative Values of various units of Electrical Resistance. (*Jenkins.*)

No.	Name of unit.	Absolute $\frac{\text{foot}}{\text{second}} \times 10^7$.	Thomson's old unit.	Jacobi	Weber's absolute $\frac{\text{metre}}{\text{second}} \times 10^7$.	Siemens.	B.A. unit, or Ohm.	Digney.	Bréguet.	Swiss.	Matthiessen.	Varley.	German miles.
	1	2	3	4	5	6	7	8	9	10	11	12	13
1	Absolute $\frac{\text{foot}}{\text{second}} \times 10^7$	1·000	0·9520	0·4788	0·3316	0·3197	0·3048	0·03289	0·03123	0·02924	0·02243	0·01190	0·005307
2	Thomson's unit . .	1·0505	1·000	0·5029	0·3483	0·3358	0·3202	0·03455	0·03279	0·03071	0·02357	0·01251	0·005574
3	Jacobi	2·088	1·988	1·000	0·6925	0·6675	0·6367	0·06869	0·06520	0·06106	0·04686	0·02486	9·01108
4	Weber's absolute $\frac{\text{metre}}{\text{second}} \times 10^7$ . .	3·015	2·871	1·444	1·000	0·9635	0·9191	0·09919	0·09416	0·08817	0·06767	0·03591	0·01655
5	Siemens (mercury) .	3·129	2·979	1·498	1·038	1·000	0·9536	0·1030	0·0977	0·0915	0·07026	0·03726	0·0166
6	**B.A. unit, or Ohm** .	**3·281**	**3·123**	**1·570**	**1·088**	**1·0486**	**1·000**	**0·1079**	**0·1024**	**0·0959**	**0·0736**	**0·03905**	**0·01741**
7	Digney.	30·40	28·94	14·56	10·08	0·0971	9·266	1·000	0·9491	0·8889	0·6822	0·3620	0·1613
8	Bréguet	32·03	30·50	15·34	10·62	10·23	9·760	1·054	1·000	0·9365	0·7187	0·3814	0·1700
9	Swiss	34·21	32·56	16·38	11·34	10·93	10·42	1·125	1·068	1·000	0·7675	0·4072	0·1815
10	Matthiessen . . .	44·57	42·43	21·34	14·78	14·23	13·59	1·66	1·391	1·303	1·000	0·5306	0·2365
11	Varley	84·01	79·96	40·21	27·85	26·83	25·61	2·763	2·622	2·456	1·885	1·000	0·4457
12	German mile . . .	188·4	179·4	90·22	62·48	60·21	57·44	6·198	5·882	5·509	4·228	2·243	1·000

Development of Heat and Work.

According to *Joule's* law, the quantity of heat, H, developed during the time, t, by a current in a circuit in which the current is I, and resistance, R, is

$$(1.)\ H = I^2 R t.$$

And since $I = \frac{E}{R}$, we have also the expressions

$$(2.)\ H = I E t,$$

and

$$(3.)\ H = \frac{E^2 t}{R}.$$

We have also the equation of the quantity, per second, $Q = \frac{E}{R}$, therefore

$$(4.)\ H = Q E t,$$

and, if q is the whole quantity passed in the time t,

$$(5.)\ H = q E,$$

and

$$(6.)\ H = Q^2 R t.$$

Any of these expressions gives the amount of heat developed by the current in the time t.

An absolute unit of work is performed, per second, by an absolute unit of electro-motive force in a circuit of one absolute unit of resistance.

Therefore the amount of work performed in one second by a current of one volt in a circuit of one ohm, will be equivalent to $\frac{10^{5 \times 2}}{10^7}$ absolute units of work. An absolute unit of work is equal to $\frac{1}{9 \cdot 81}$ part of a gramme raised 1 metre; and therefore $\frac{10^{5 \times 2}}{10^7}$ or 1000 absolute units of

work are equal to $\frac{10^8}{9{\cdot}81}$ grammes raised one metre, or to 101·92 metre-grammes. And since one unit of heat is equivalent to 423·5 (metre-gramme) units of work, a B. A. unit of electro-motive force in driving, during one second, through a resistance of one ohm performs work which is converted into 0·2405 units of heat.

Therefore the heat H (in units of heat) developed in t seconds, when R and E (of the above formulæ) are expressed in B. A. measures, is as follows:—

$$H = 0{\cdot}2405 \frac{E^2 t}{R}$$

And the work W (in metre-grammes) performed by the current in driving through the circuit in the time t seconds will be equivalent to

$$W = 101{\cdot}92 \frac{E^2 t}{R}$$

GALVANISM.

Ohm's Law.

1. Let E be the electro-motive force,
   R the resistance, and
   I the current or quantity, per second, in any galvanic circuit;

then $$I = \frac{E}{R}.$$

2. The resistance R may consist of r that of the battery, and G that which is exterior to it, in which case

$$I = \frac{E}{G + r}.$$

3. When a battery of n equal elements is connected up in series, each element having the resistance, r,

$$I = \frac{nE}{G + nr}.$$

4. If the n equal elements are connected up all parallel to each other,

$$I = \frac{nE}{nG + r}.$$

5. When the elements have different resistances, r_1, r_2, r_3 . . . r_n, their electro-motive forces being alike, then in series,

$$I = \frac{nE}{G + r_1 + r_2 + r_3 + \ldots + r_n}.$$

6. When they are parallel,

$$I = \frac{E\left(\frac{1}{r_1} + \frac{1}{r_2} + \frac{1}{r_3} + \ldots \frac{1}{r_n}\right)}{1 + G\left(\frac{1}{r_1} + \frac{1}{r_2} + \frac{1}{r_3} + \ldots \frac{1}{r_n}\right)}.$$

7. The battery consisting of n elements, whose electromotive forces are E_1, E_2, E_3, . . . E_n, and whose resistances are r_1, r_2, r_3, . . . r_n, connected in series,

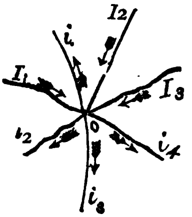
$$I = \frac{E_1 + E_2 + E_3 + \ldots + E_n}{G + r_1 + r_2 + r_3 + \ldots + r_n}.$$

8. When these unequal elements are connected parallel

$$I = \frac{\frac{E_1}{r_1} + \frac{E_2}{r_2} + \frac{E_3}{r_3} + \ldots + \frac{E_n}{r_n}}{1 + G\left(\frac{1}{r_1} + \frac{1}{r_2} + \frac{1}{r_3} + \ldots + \frac{1}{r_n}\right)}.$$

Kirchhoff's Laws.

I. *The sum of the currents in all those wires which meet in a point is equal to nothing.*



Let the currents which approach the point o, be I_1, I_2, I_3, and those which leave it be i_1, i_2, i_3, i_4, then

$$I_1 + I_2 + I_3 - i_1 - i_2 - i_3 - i_4 = 0.$$

2. *The sum of all the products of the currents and resistances in all the wires which form an enclosed figure is equal to the sum of all the electro-motive forces in the same circuit.*

Laws of Dynamic Electric Circuits.

I. The strength of a galvanic current is equal to the quantity of electricity flowing per second; and is the same in every point of an undivided conductor.

II. The strength of the current is proportional to the electro-motive force, when the resistance remains constant.—(*Ohm.*)

III. The current strength is inversely proportional to

the resistance of the conductor; and therefore directly proportional to its conducting power.—(*Ohm.*)

IV. The current strength is equal to the electro-motive force divided by the resistance.

V. The current strength obtained with a battery of given surface is at its maximum when the plates are so divided that the internal resistance of the battery is equal to that of the circuit without.—(*Jacobi.*)

VI. The sum of the current strengths in all those wires which converge to a point is equal to nothing.—(*Kirchhoff.*)

VII. The sum of all the products of the intensities and resistances in all the wires which form an enclosed figure is equal to the sum of all the electro-motive forces in the same circuit.—(*Kirchhoff.*)

VIII. If, in any system of circuits, containing any electro-motive forces, a conductor exists in which the current-strength is equal to nothing, the currents in the remaining circuits will not be altered, in the least, if the circuit of the conductor in question be separated or removed together with whatever electro-motive force it may contain.

IX. If the conductor in question contain no electro-motive force, the currents will not be altered if, after its removal, the points between which it previously existed be connected directly with each other.—(*Bosscha.*)

X. If, on the other hand, it contained an electro-motive force, the points can only be joined again, whilst retaining the balance, by inserting between them an equivalent electro-motive force, but irrespective of the resistance which may accompany it.—(*Bosscha.*)

XI. In a system of linear conductors, containing electro-motive forces, the current set up in any conductor, A, by any electro-motive force contained in any other conductor, B, will be identically the same as that which would be set up in B by an equal electro-motive force in A.—(*Bosscha.*)

XII. If, in a system of electro-motive forces and conductors, there be two of the latter, say A and B, in which the electro-motive force in A occasions no current in B, whatever current may be circulating in B will not be affected if A be interrupted or removed; nor will the current in A be altered if B be interrupted or removed, however the electro-motive forces in the other circuits may be arranged.—(*Bosscha.*)

XIII. In any linear conductor through which a current of electricity is flowing, the difference of potential, between any two points with a given resistance between them is the same as that between any other two points having between them an equal resistance.—(*Ohm.*)

Laws of Volta-induction.

I. In a secondary closed circuit, the excited induction current is proportional to the current strength in the primary circuit.

II. The induction currents arising from the action of a galvanic current *upon itself* are, both on breaking and making the circuit, equally great, so long as the inducing current strength remains equal.—(*Edlund.*)

III. When a metallic closed circuit and a conductor

through which an electric current is circulating are either brought nearer to each other or separated, a current is induced in the metallic closed circuit. This current is in the reverse direction to that which would have been necessary to effect the approach or separation of itself.—(*Lenz.*)

IV. The electro-motive force which a magnet excites in a helix of wire is, *cæteris paribus*, proportional to the number of convolutions of the wire.—(*Lenz.*)

V. The electro-motive force which a magnet excites in a surrounding helix is equal, whatever may be the radius of the coil. Therefore, the currents induced in the different rings of wire are inversely proportional to their diameters.—(*Lenz.*)

VI. The electro-motive force excited by a magnet in a helix of given number of turns is the same, whatever may be the thickness or conducting power of the wire.

VII. The strengths of the induction currents in different spirals of equal number of turns are proportional to their conducting powers.

VIII. The longer the connecting wires are, so much more numerous should be the convolutions in order to obtain the maximum current.

IX. The more turns which can be put next to each other close by the magnet or magnetised armature, the fewer turns will be necessary to give a maximum current.

X. The maximum of an induction current is proportional to the strength of the inducing magnet.—(*Lenz.*)

XI. The retardation of the *development* of magnetism in soft iron cores which are *wholly* covered by helices,

depends principally upon the opposite currents induced in the helices themselves. The magnetism of the simultaneous currents induced in the periphery of the core, and the coercive force of the iron, are of less influence.—(*Beetz.*)

XII. The retardation of the *disappearance* of the magnetism from soft iron cores which are *wholly* covered with galvanic helices, depends however principally upon the formation of currents in the periphery of the soft iron cores.—(*Beetz.*)

XIII. The retardations of development and disappearance of magnetism in soft iron cores which are only *partially* covered with helices, depends principally upon the magnetic inertia of the iron.

Laws of Magnetism.

I. A magnetic field is any space in the neighbourhood or under the influence of a magnet.—(*B. A. Report.*)

II. The unit pole is that which at an unit (= 1 metre) distance from a similar pole is repelled with unit force $\left(= \frac{1}{9 \cdot 81} \text{ grammes}\right)$.—(*Ib.*)

III. The intensity of a magnetic field at any point is equal to the force which the unit pole would experience at that point.—(*Ib.*)

IV. The direction of the force in the field is the direction in which any pole is urged by the magnetism of the field; this is the direction which a short, balanced, freely suspended magnet would assume.

v. An uniform magnetic field is one in which the intensity is equal throughout, and hence the lines of force parallel.—(*Thomson.*)

vi. Opposite poles attract each other; similar poles repel each other.

vii. The forces directed from any magnetic point upon equal masses are reciprocally proportional to the square of the distance.—(*Muschenbröck.*)

viii. When two magnets are very small and the distance between them very great in proportion to their length, the magnetic action between them is reciprocally proportional to the cube of their distance.—(*Gauss.*)

ix. The force directed from any magnetic point upon any other mass upon which it acts is reciprocally proportional to the square of the distance. The total action between them both is, however, reciprocally proportional to the third power of the distance, when the latter is great.—(*Gauss.*)

x. Magnetic forces between a suspended magnet and any mass upon which it acts are proportional to the square of the number of oscillations which (under their mutual action alone) the same magnet makes in a given time.—(*Coulomb.*)

xi. Magnetic forces between a suspended magnet and any magnetic mass are inversely proportional to the square of the time which the suspended magnet takes to complete one oscillation.—(*Coulomb.*)

xii. The attraction of a magnet for an armature is proportional to the square of its free magnetism.

xiii. The magnetism excited at any given transverse

section of a magnet is proportional to the square root oı the distance between the given section and the nearest end of the magnet.—(*Dub.*)

XIV. The free magnetism at any given transverse section of a magnet is proportional to the difference between the square root of half the length of the magnet and the square root of the distance between the given section and the nearest end.—(*Dub.*)

XV. *The mean horizontal component of the earth's magnetism*, in England, for 1865, was = 1·764 (metrical) units of force; *i.e.*, a unit pole weighing one gramme, and free to move in a horizontal plane, would, under the action of the horizontal force of the earth's magnetism, acquire, at the end of a second, a velocity equal to 1·764 metres per second.

Laws of Electro-magnetism.

I. If we imagine a positive current to flow through the axis of an ordinary corkscrew, the tip of the latter, in any position, represents the direction assumed by the north end of a magnet. If a current circulate in the corkscrew-helix in the direction in which it is turned, a soft iron core in its centre will have its north end towards the tip.—(*L. Clark.*)

II. The total effect of any infinitely long and straight conductor upon any magnetic element is inversely proportional to the perpendicular distance between element and the conductor.—(*Biot and Savart.*)

III. A magnetic element in the axis of a circular current is attracted or repelled from the centre with a

force which is directly proportional to the superficial content of the circle and inversely to the third power of the distance of the element from the periphery.—(*Weber.*)

IV. A circular current flowing in the plane of the magnetic meridian deflects a magnetic needle (which is infinitely short in comparison with the radius of the current) so that the tangent of the angle of deflection is proportional to the strength of the current.—(*Weber.*)

V. The magnetic intensity of a single deflected needle is without influence upon the angle of deflection.—(*Weber.*)

VI. If the circular conductor be turned after the deflected needle until the latter again coincides with the plane of the former, the current strength is proportional to the sine of the angle through which the conductor is turned.

VII. In electro-magnets, the south pole is always found at that end where the positive current enters a right-handed helix.

VIII. The free magnetism of the end faces of an electro-magnet is proportional to the current strength in its helix.—(*Dub.*)

IX. The attraction between electro-magnets is proportional to the square of the strength of the magnetising current.

X. The material and the thickness of the helix wire of an electro-magnet are, when the current is equal, without influence upon its magnetism.—(*Lenz.*)

XI. The free magnetism of an electro-magnet, with a

given current strength, is directly proportional to the number of turns of its helix.—(*Jacobi.*)

XII. Its attraction is proportional to the square of the number of convolutions.—(*Dub.*)

XIII. The attraction between two electro-magnets is proportional to the sum of the products of the current strength and number of convolutions of both helices.

XIV. The force with which a bar of soft iron is attracted by a galvanic helix is proportional to the square of the product of current strength and number of convolutions of the helix.—(*Dub.*)

XV. The force with which a saturated steel magnet is attracted by a galvanic helix is directly proportional to the product of the current strength and number of convolutions.

XVI. The free magnetism of a solid cylindrical soft iron core of given length is, *cæteris paribus*, proportional to the square root of its diameter.—(*Nicklès.*)

XVII. The free magnetism at the poles of a horse-shoe magnet is, *cæteris paribus*, proportional to the square root of the length.

XVIII. The free magnetism of any given transverse section of an electro-magnet is proportional to the difference between the square root of half the length and the square root of the distance of the given section from the nearest end.—(*Dub.*)

XIX. The poles of an electro-magnet attract most favourably when their faces have the same area as the transverse section of the magnet.

XX. The attraction between an electro-magnet and

its armature increases when the mass of the armature is increased.

XXI. The magnetising powers of coils of one and the same metal, with the same surface of battery plates, arranged so as to give a maximum strength of current in each case, are as the square roots of the weights of the metallic wire used.—(*Menzzer.*)*

Example.—Let us select two electro-magnet coils, No. 1. of which has 36 lbs. of copper wire, giving 25 ohms resistance; the other, No. 2, consists of 120 lbs. of copper wire, having a resistance of 6·3 ohms. The battery which we use in each case consists of 104 elements, each having 0·5 square feet surface, and an internal resistance of 0·25 ohms.

First, it is evident that with No. 1 coil, we must, in order to obtain with the given battery the greatest current, connect up the elements all in series, which will give 26 ohms. Secondly, for No. 2 coil we must connect up the battery, evidently in two parallel rows of each 52 elements, giving a resultant resistance of 6·5 ohms. Both these methods of connection are according to the rule given at page 94, and both, although not exact, are the nearest approximations to the maxima possible without cutting the plates.

And when we have thus obtained for each its maximum current with the given battery, the relations of their magnetising power will be No. 1 : No. 2 :: $\sqrt{36} : \sqrt{120}$ or :: 6 : 11 nearly.

Therefore the magnetising force of No. 2 coil will be

$$\frac{\sqrt{120}}{\sqrt{36}} = \frac{11}{6} = 1 \cdot 83 \text{ times that of No. 1.}$$

Laws of Electro-static Charge.

1. The electro-static charge or quantity of electricity held inductively upon the outer surface of any insulated body varies directly as the tension or difference of potentials between the body and surrounding objects.

* Pogg. Ann., Nov. 1, 1865.

2. The static charge in any part of a submarine cable through which a galvanic current is flowing to earth, varies directly as the distance from "earth," at which it is zero.

3. If a current flow through a telegraph wire or cable conductor, one end of which is to earth, and if the line be divided into any number of equal parts, the proportion of static charge in each part commencing from the earth end will be as the alternate odd numbers 1 : 3 : 5 : 7 : and so on. Consequently, if the line be divided into two equal parts, their charges will be as 1 to 3.

4. The quantity of electricity accumulated inductively between any two conducting surfaces, varies directly as the distance between them or as the thickness of the intervening dielectric.

Free and Bound Charge.

When we charge one side, A, of a condenser by any source of electricity, it induces a charge on the other side, B, which is entirely bound, whilst the communicated charge is partly bound by B and partly by surrounding objects.

Suppose we charge the upper side of a condenser with a quantity of electricity = Q vebers, whilst the under side is connected with earth. The communicated charge will then induce, in the under side, a charge = n times Q or Q n (n being a fraction). And this quantity Q n will exert an inducing influence back again in the upper side and hold a quantity = n times Q n or Q n^2 of the original charge bound, whilst the rest of it will be so-

called free electricity. The amount of this free electricity, q, will therefore be equal to

$$q = Q - Q n^2 = Q(1 - n^2) \text{ vebers}:$$

the value of n, which is always less than 1, being dependent upon the thickness and inductive capacity of the dielectric medium.

Now q is evidently the quantity of electricity, in vebers, which would be communicated to the upper side of the condenser, at the potential of the source, were the under side not coated, or insulated from earth. Therefore by such connection with earth, the quantity of electricity received by the condenser is obviously very much greater, since

$$Q = q \frac{1}{1 - n^2} \ldots \text{ vebers},$$

and as n is necessarily always less than 1, it follows that $\frac{1}{1 - n^2}$ must be also greater than 1 and $Q > q$.

Let n, for example, be $0{\cdot}95$ for any given condenser, then we shall have

$$Q = q \frac{1}{1 - 0{\cdot}95^2},$$

or

$$Q = q \, 10{\cdot}259.$$

WHEATSTONE'S BALANCE.

The four resistances are a, b, c, and x, the currents being respectively i_1, i_2, i_3, and i_4. The circuit, r, contains a galvanometer; and the circuit, R, a battery whose

electro-motive force is E. According to Kirchhoff's laws:—

$I = i_1 + i_2 = i_3 + i_4$

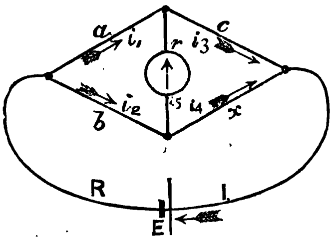
1.) $i_3 - i_5 - i_1 = 0$;

2.) $i_2 - i_4 - i_5 = 0$;

3.) $i_3 c - i_4 x + i_5 r = 0$;

4.) $i_1 a + i_3 c - i_2 b - i_4 x = 0$.

When the resistances are arranged so that no current



goes through the circuit r, that is to say, $i_5 = 0$, and we eliminate the values of the currents from the above, we get

$$\frac{a}{b} = \frac{c}{x};$$

a, b, and c being known, the unknown resistance x is

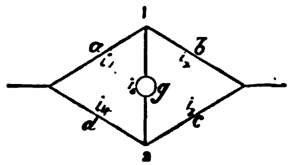
$$x = c\frac{b}{a}.$$

Relation of Resistances to Sensibility of Galvanometer (*Schwendler*).

If a, b, c, and d are the four resistance-sides of a Wheatstone's bridge, the resistance, g, of the galvanometer, which gives the greatest sensibility with a given battery and weight of copper wire is

$$g = \frac{(a + d)\,(b + c)}{a + b + c + d}.$$

This is equivalent to the resistance of the two circuits *a d* and *b c*, taken parallel between the points 1 and 2.



Therefore, *to raise the magnetic moment of a galvanometer to its maximum, its resistance must be equal to the parallel resistance of the two double branches which are parallel with the galvanometer.*

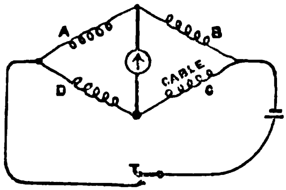
This law, which is approximately true, can only be correct when the insulating covering of the galvanometer wire, for all the different gauges, bears a constant proportion to the diameter of the wire itself. It is, of course, practically impossible to adjust the galvanometer resistance for every resistance which has to be measured; but when a galvanometer is being constructed for any special purpose—as, for instance, the measurement of knot lengths of cable core conductivity—regard may be had with profit to the above law.

Arrangement of Balance for reading off directly the Resistances of Copper per Knot without Calculation.

For this purpose the sides of the balance are arranged as follows:

A = a *constant* resistance of 2029 ohms.

B = a *variable* resistance box, which is adjusted each time to exactly as many ohms as there are *yards* in the length of the cable.



C = the conductor of the cable.

D = an adjustable resistance, expressing the resistance of the conductor in ohms per knot.

The cable (whose length, L, in yards is known) is first inserted in its place; then the box, B, arranged so as to have L ohms resistance. Equilibrium of the galvanometer needle is obtained by adjusting the value of D as in ordinary balances. When this is done, supposing the whole resistance of the conductor to be C ohms, we have

$$\frac{A}{B} = \frac{D}{C} = \frac{2029}{L}$$

Therefore $D = C\frac{2029}{L}$ = the resistance of the conductor in ohms, per knot.

This method is very convenient when the conductors are measured always at the same temperature, as the separate knot lengths of core are at the G. P. Works, as it saves much time in reducing the observed values. For such measurements the resistance box, D, should

if possible, be constructed with values from 0·01 to 50 ohms.

Balance for reading off the Insulation Resistance in Megohms per Knot without Calculation.

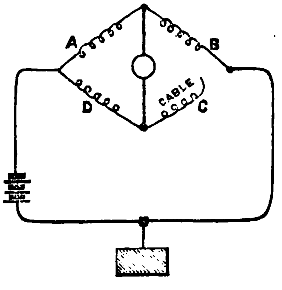
This method is analogous to the last; but is not so exact on account of the difficulty of preventing heating of the coils.

A is a variable resistance box adjusted in each experiment to the same number of ohms that there are *knots* length in the *cable;*

B is a constant resistance of *one megohm;*

C is the cable resistance in megohms; and

D is a resistance which is varied until equilibrium is obtained, and which then represents the resistance of insulation in megohms per knot.



In this case (supposing the length of the cable to be L knots) we have

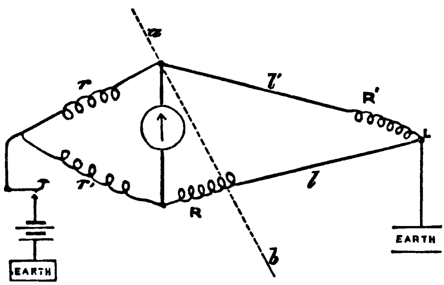
$$\frac{A}{B} = \frac{D}{C} = \frac{L}{1}$$

Therefore D = C L = the total resistance of the insula-

tion multiplied into the length in knots, or the insulation per knot, in megohms.

For the periodical tests of a submerged cable, whose total insulation resistance is about 1 megohm, this arrangement would be found convenient; in which case A and B would be constant values, and the insulation resistance, per knot, would be read off directly from D.

Elimination of leading wires—The error due to the unknown temperature of the leading wires may be eliminated by the following contrivance. The apparatus



to the left hand of the dotted line *a b* is in the operating-room, that on the right-hand side is without. The leading wires l and l' are of the same metal (copper usually), of the same dimensions and conducting power, and are spun up close together in a suitable cable, so that, at any given point, they both have the same temperature and resistance. The junction of l and R′ is to earth; that of l' and R′ is insulated; r is made equal to r', therefore

$$R' + l' = R + l$$
$$R' = R.$$

When the readings with positive and negative currents differ (*Schwendler*).

$$x = \frac{bf(a+b)(W'+W'')+b^2(aW'+2W'W''+aW'')}{ab(W'+W'')+2af(a+b)+2a^2b}$$

a and b are the two branch resistances; W′ the adjusted resistance with $+$; W″ that with negative current towards a and b; and f the battery resistance.

Practically we may neglect f, and the required resistance becomes

$$x = \frac{b}{a}\left(\frac{W'+W''}{2} - \frac{(W''-W')^2}{2(W'+W'')+4a}\right)$$

If W′ and W are not very different

$$x = \frac{b}{a} \cdot \frac{W'+W''}{2}$$

If E is the electro-motive force of the measuring battery and e that in one of the sides,

$$\pm e = E\frac{(W''-W')b}{(W'+W'')b+2f(a+b)+ab}$$

Or by neglecting f, the battery resistance,

$$\pm e = \frac{W''-W'}{W'+W''+a} \cdot E$$

To estimate the true resistance when balance cannot be obtained at zero :—

When the true resistance is between two plugged holes; one giving a deflection $\alpha°$, when too small, and the other a deflection $\alpha_1°$, when too great, the true resistance is the smaller of the two readings from the resistance box, plus

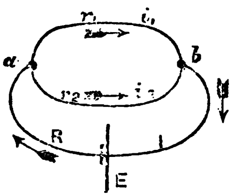
$$\frac{\alpha}{\alpha+\alpha_1} \text{ ohms.}$$

Thus in measuring a length of wire, we plugged 110 ohms, and found a deflection of 2° to the right; but with 109 ohms, which was too small, we got 3° to the left; the true resistance was therefore

$$109 + \frac{3}{3 + 2} = 109 \cdot 6 \text{ ohms.}$$

SHUNT AND DERIVED CIRCUITS.

Let R_1, r_1, and r_2 be the resistances of the three lines



which connect the points *a* and *b*; and I, i_1, and i_2, the currents in the same produced from the battery E.

$$I = E \frac{r_1 + r_2}{R r_1 + R r_2 + r_1 r_2};$$

$$i_1 = E \frac{r_2}{R r_1 + R r_2 + r_1 r_2};$$

$$i_2 = E \frac{r_1}{R r_1 + R r_2 + r_1 r_2}.$$

The resistance R′ **of the whole circuit** through which the current circulates is

$$R' = R + \frac{r_1 r_2}{r_1 + r_2}.$$

The resistance of the parallel shunt circuits is therefore $\left(\frac{r_1 r_2}{r_1 + r_2}\right)$ equal to the product of their resistances divided by their sum.

Galvanometers and Shunts.

The joint resistance of a galvanometer and shunt is as above, $\frac{\text{galv.} \times \text{shunt}}{\text{galv.} + \text{shunt}}$.

The multiplying power of any shunt is equal to

$$\frac{\text{galv.} + \text{shunt}}{\text{shunt}}, \text{ or } \frac{\text{galv.}}{\text{shunt}} + 1.$$

To prepare any given Shunt.—It is sometimes necessary to prepare a shunt having some definite multiplying power, as, for instance, 10, 100, etc.; if we call the resistance of the galvanometer G, and of the required shunt s, and let n be the multiplying power we require, then

$$s = \frac{G}{n - 1}.$$

For example, if a galvanometer of 1089 units required a 100th shunt, the resistance of the latter would be

$$\frac{1089}{100 - 1} = \frac{1089}{99} = 11.$$

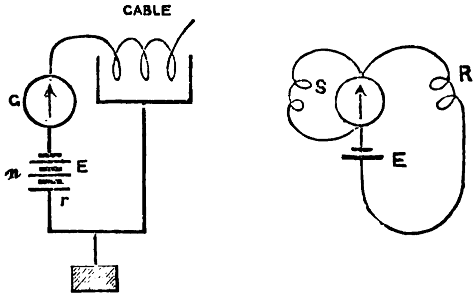
A parallel circuit (r_1) added to a line of known resistance, r ohms, giving a combined resistance, R ohms; the resistance of the added circuit is

$$r_1 = \frac{R\,r}{r - R} \quad . \quad . \quad . \quad \text{ohms.}$$

INSULATION RESISTANCE.

Insulation of Cable by deflection.—Let the unknown insulation resistance of the Cable be x; the galvanometer resistance, G; the battery resistance, r; the

number of elements, n; the electro-motive force of each element, E; and the observed deflection of the needle, ϕ.



The Cable is then removed, and a known resistance substituted for it of such value as to make the whole resistance of the circuit = R ohms; the battery is reduced to a single element; the shunt, s, is inserted across the galvanometer coils; and the observed deflection becomes ψ.

The resistance of the Cable insulation is then

$$x = R\frac{\psi}{\phi}n\left(1 + \frac{G}{s}\right) - (G + r) \text{ (ohms).}$$

As $(G + r)$ is, however, very small in comparison with x, in practice it is neglected, and

$$x = R\frac{\psi}{\phi}n\left(1 + \frac{G}{s}\right) \text{ (ohms).}$$

If the length of the cable be l yards, its resistance, per knot, is

$$x_k = \frac{l}{2029} R\frac{\psi}{\phi}n\left(1 + \frac{G}{s}\right) \text{ (ohms).}$$

If a sine galvanometer be used

$$x = R \frac{\sin \psi^\circ}{\sin \phi^\circ} n \left(1 + \frac{G}{s}\right) \text{ (ohms)},$$

and

$$x_k = \frac{l}{2029} R \, . \frac{\sin \psi^\circ}{\sin \phi^\circ} n \left(1 + \frac{G}{s}\right) \text{ (ohms)}.$$

The most convenient way of employing this test is to make the shunt = $\frac{1}{99}$th of the galvanometer resistance $\left(\text{or } s = \frac{G}{99}\right)$. The resistance, R, is then made = 10,000 ohms, or, more exactly, 10,000 less the resistance of the single element and the shunt.

The resistance of the whole cable is then

$$x = \frac{\psi}{\phi} n \text{ meghoms.}$$

And its resistance, per knot,

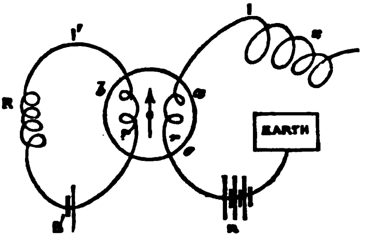
$$x_n = \frac{\psi}{\phi} \cdot \frac{l}{2029} \cdot n \text{ (meghoms).}$$

Insulation of cable by differential method (*Siemens*).—The galvanometer has two separate coils, a and b, whose magnetic effects upon the needle are unequal and opposite.

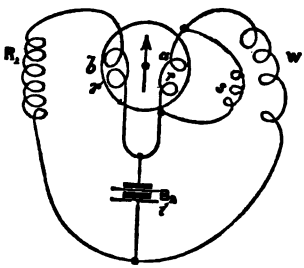
r = resistances of a and B.
r' = resistances of b and B′.
E = Electro-motive force of battery B.
E′ = Electro-motive force of battery B′

R = adjustable resistance inserted in the circuit of *b*.

x = unknown resistance of cable.



The resistance, R, is adjusted until the needle remains over the zero line. The cable is then removed, and a known resistance, W, inserted in its stead; the ends of



the coils, *a* and *b*, are connected together with one pole of a single element, B_2; and the resistance R_1 readjusted until the needle points to zero.

Then the resistance of the cable is

$$x = \frac{W + r}{R' + r'} \cdot \frac{E}{E'} (R + r') \text{ (ohms).}$$

If in taking the latter part of this test the operator use a shunt, *s* (shown in dotted lines), the value of x becomes

$$x = \frac{W(r + s) + rs}{(R' + r')s} \cdot \frac{E}{E'} (R + r').$$

The proportions

$$\frac{W + r}{R' + r'} = \frac{m}{m'}$$

and

$$\frac{W(r + s) + r s}{(R' + r')\, s} = \frac{m}{m'}$$

give the relation between the opposite magnetic effects of the coils, a and b, upon the needle when equal currents circulate in them; m being that of coil a, and m' that of coil b.

Insulation of cable, by loss of charge (*Siemens*).—Let the instantaneous discharge from a given cable (or its full tension) be C; the discharge after t minutes (or its reduced tension) be c; and the electro-static capacity of the cable be F microfarads.

Then the insulation resistance R_t, after t minutes, is

$$R_t = 26{\cdot}06 \, \frac{t}{F\,(\log C - \log c)} \text{ (megohms).}$$

Example.—A knot length of French Atlantic cable had an electro-static capacity (F) = 0·3992 microfarads. The instantaneous discharge (C) gave 332 divisions of the scale; the discharge (c), after 1 minute, gave 202 divisions. Its resistance was therefore

$$R = 26{\cdot}06 \times \frac{1}{{\cdot}3992\,({\cdot}5211 - {\cdot}3054)} = 300{\cdot}3 \text{ megohms.}$$

Where the fall is from full to half tension, or the reduced discharge, $c = \frac{C}{2}$, then

$$R_t = 86{\cdot}56 \, \frac{t}{F} \text{ (megohms).}$$

The resistance (after one minute) obtained by this for-

mula agrees with that measured by the direct methods, if the cable be charged 10 seconds before taking the reading, C; and again 10 seconds before insulating it preparatory to observing the throw, *c*.

For deducing in this way the resistance of a length of cable core, it is more correct to measure its capacity, F, than to calculate it from the length of the piece and the mean capacity of the cable.

With a cable of high insulation resistance, of which the loss is very small, great accuracy must be used to measure the loss; the following plan by Dr. Esselbach is the simplest:—

(1). Connect up in the ordinary way for taking insulation.

(2). Take the immediate charge through the galvanometer with a shunt, holding the key down for at least ten seconds. Then leave the cable insulated with its charge for one minute or more.

(During this time, if necessary, increase the resistance of the shunt.)

(3). At end of the one or more minutes, recharge cable by pressing down the key as before, and the throw of the needle will represent the quantity required to refill the cable to its original charge, and is exactly equal to the loss during the time the cable remained insulated.

To calculate the time T of falling from full to any given tension (if the electrification and resistance remain constant)—

$$T = \frac{\log C - \log p}{\log C - \log c} \times t \text{ (seconds)}.$$

Where C = original charge or full tension; c = observed charge (or reduced tension) remaining after t seconds; p = quantity of charge or tension required to be in the cable at the time T.

It being usually required to know the time a cable or wire will fall to half tension, the formula becomes

$$T = \frac{\cdot 30103}{\log C - \log c} \times t \text{ (seconds).}$$

This formula may be written thus :—

$$T = \frac{0\cdot 30103\, t}{2\cdot 000 - \log (100 - n)},$$

where n = percentage of loss in interval of time t (*Preece*).

As electrification goes on during the time the cable is insulated, t should be made as short as possible.

The percentage of loss is the same for every interval, *i. e.*, the percentage of loss of the original charge in the first minute is the same as the percentage of the loss of the remaining charge in the next minute, and so on.

At high temperatures (75° Fahr.) the loss of charge during one minute of average telegraph cores varies from 30 to 50 per cent., according to the insulation and the material.

Specific Insulation Resistance.

The resistance, per knot, of a cable being R megohms, its specific resistance, r, is

$$r = R \cdot \frac{2\cdot 728}{\log D - \log d} \quad . \quad . \quad . \quad \text{megohms.}$$

The specific resistance is assumed to be that of a cubic knot of the insulator.

An ordinary gutta-percha cable at 75° F. falls from tension to half tension in about 100 seconds, irrespectively of its dimensions.

Resistance in Megohms of any Dielectric whose Electro-static capacity = one Microfarad.

$\left(\frac{C}{c}\right.$ observed after 1 minute.$\left.\right)$

$\frac{C}{c}$	Loss of charge per cent.	Resistance megohms.	$\frac{C}{c}$	Loss of charge per cent.	Resistance megohms.	$\frac{C}{c}$	Loss of charge per cent.	Resistance megohms.	$\frac{C}{c}$	Loss of charge per cent.	Resistance megohms.
1·01	1·0	6059	1·26	20·6	259·5	1·51	33·8	145·6	1·76	43·2	106·1
1·02	2·0	3030	1·27	21·3	251·0	1·52	34·2	143·3	1·77	43·5	105·1
1·03	2·9	2036	1·28	21·9	243·1	1·53	34·6	141·1	1·78	43·8	104·1
1·04	3·8	1532	1·29	22·5	235·6	1·54	35·1	138·9	1·79	44·1	103·1
1·05	4·7	1229	1·30	23·1	228·8	1·55	35·5	136·9	1·80	44·4	102·0
1·06	5·7	1030	1·31	23·7	222·1	1·56	35·9	134·9	1·81	44·8	101·1
1·07	6·6	886·4	1·32	24·2	216·1	1·57	36·3	133·0	1·82	45·1	100·2
1·08	7·4	780·2	1·33	24·8	210·3	1·58	36·7	131·1	1·83	45·4	99·3
1·09	8·3	696·6	1·34	25·4	205·0	1·59	37·1	129·4	1·84	45·7	98·4
1·10	9·1	629·4	1·35	25·9	200·0	1·60	37·5	127·7	1·85	45·9	97·5
1·11	9·9	575·2	1·36	26·5	195·2	1·61	37·9	126·0	1·86	46·2	96·7
1·12	10·7	529·5	1·37	27·0	190·6	1·62	38·3	124·4	1·87	46·5	95·9
1·13	11·5	490·7	1·38	27·5	186·3	1·63	38·7	122·8	1·88	46·8	95·0
1·14	12·3	457·9	1·39	28·1	182·2	1·64	39·0	121·3	1·89	47·1	94·2
1·15	13·0	429·2	1·40	28·6	178·3	1·65	39·4	119·8	1·90	47·4	93·5
1·16	13·8	403·9	1·41	29·1	174·6	1·66	39·8	118·4	1·91	47·7	92·7
1·17	14·5	382·0	1·42	29·6	171·1	1·67	40·1	117·0	1·92	47·9	92·0
1·18	15·3	362·4	1·43	30·1	167·8	1·68	40·5	115·4	1·93	48·2	91·2
1·19	16·0	344·6	1·44	30·6	164·5	1·69	40·8	114·3	1·94	48·5	90·5
1·20	16·7	329·0	1·45	31·0	161·4	1·70	41·2	113·0	1·95	48·7	89·9
1·21	17·4	314·1	1·46	31·5	158·5	1·71	41·5	111·8	1·96	49·0	89·2
1·22	18·0	301·6	1·47	32·0	155·7	1·72	41·9	110·6	1·97	49·2	88·5
1·23	18·7	289·8	1·48	32·4	152·7	1·73	42·2	109·4	1·98	49·5	87·8
1·24	19·4	279·0	1·49	32·9	150·5	1·74	42·5	108·3	1·99	49·7	87·2
1·25	20·0	268·9	1·50	33·3	148·0	1·75	42·9	107·2	2·00	50·0	86·6

To find the resistance, in megohms, of an insulator whose capacity, in microfarads, is known, the tension or discharge, C, being observed immediately after contact, and *c* after some minutes.

Rule.—Multiply the value given in the above table by the number of minutes (which the cable remains

insulated before reading c), and divide by the capacity in microfarads.

Example.—A knot length of Atlantic core lost 40% of its charge in 1 minute. Its capacity was 0·41 microfarads. Therefore from above table,

$$\frac{117 \times 1}{0{\cdot}41} = 285 \text{ megohms resistance.}$$

Loss of tension.—The percentage loss of tension or charge, by an insulated core is independent of both its size and form, and is dependent only upon its material.

Thus a coated plate of india-rubber of any size and thickness will lose the same percentage of charge per minute as a cable coated in the same material would, whatever might be its length or thickness of insulator.

We shall see further on (p. 68) that

$$\mathrm{R\,F} = rf$$

or

$$\mathrm{R} = \frac{rf}{\mathrm{F}}$$

and (p. 35)

$$\mathrm{R} = \frac{26{\cdot}06\, t}{\mathrm{F} \log \frac{\mathrm{C}}{c}}$$

therefore

$$rf = \frac{26{\cdot}06\, t}{\log \frac{\mathrm{C}}{c}}$$

and

$$t = \frac{rf \log \frac{\mathrm{C}}{c}}{26{\cdot}06}$$

That is to say, the time of falling from C to c is proportional to the specific resistance (corresponding with its electrification and temperature at the moment), and

specific inductive capacity of the dielectric and to the log. of $\frac{C}{c}$.

RATIO $\frac{D}{d}$ FOR STRAND AND SOLID CONDUCTORS.

The approximate ratio $\frac{D}{d}$ for insertion in the insulation and induction formulæ may be calculated from the weights, W lbs. per knot of insulator, and *w* lbs. per knot of copper, as follows :—

1. *A solid wire covered with gutta-percha* :—

$$\frac{D}{d} = \sqrt{1 + 8{\cdot}93\,\frac{W}{w}}.$$

2. *A strand covered with gutta-percha* :—

$$\frac{D^*}{d} = 1{\cdot}05\sqrt{1 + 6{\cdot}97\,\frac{W}{w}}.$$

3. *A solid wire covered with Hooper's material* :—

$$\frac{D}{d} = \sqrt{1 + 7{\cdot}3\,\frac{W}{w}}.$$

4. *A strand covered with Hooper's material* :—

$$\frac{D^*}{d} = 1{\cdot}05\sqrt{\left(1 + 5{\cdot}7\,\frac{W}{w}\right)}.$$

* The value of $\frac{D}{d}$ given by these formulæ are the ratios between the diameter of the insulator and the mean diameter of the strand. If the extreme diameter of the strand were inserted in the formulæ for calculating insulation, inductive capacity, etc., the resulting electrical conditions of the cable would be misrepresented; therefore the measured diameter of the copper is diminished 5%, which is equivalent to increasing the measured ratio by 5%.

The accumulation joint test (*Clark*).—This method is very suitable for measuring the insulation of joints, or other very short lengths of core. The battery is connected with the conducting wire, and the length of core to be tested is immersed in an insulated suspended trough. A condenser is connected with the water of the trough, so that all the electricity which escapes from the joint or length of wire in a given time (usually one minute) is collected in the condenser. At the end of the minute the whole of this charge is suddenly discharged by a key through a galvanometer, the deflection of which indicates the quantity which has leaked through the joint in the given time. Joints are now generally tested by this plan, the leakage from 12 to 20 feet of perfect cable forming the standard of comparison. If the leakage from a joint exceeds this quantity, it is considered faulty, and rejected.

FAULTS IN CABLES.

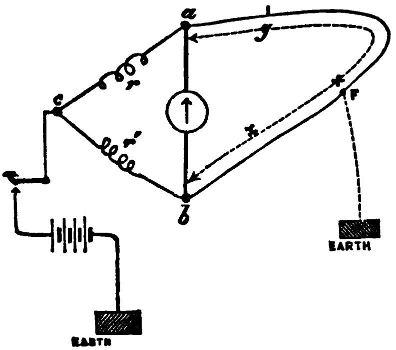
Murray's Loop Method.

In this method the resistance of the fault is eliminated, that of the insulation supposed to be infinite in comparison with it.

Let the two adjustable resistances, r and r', be connected together with the battery-contact in the point, c; the galvanometer be connected between a and b; and the two ends of the cable be connected with the same points.

Let the distance of the fault from the ends a and b be

respectively y and x knots, and the total length $(x + y)$ be L knots.



Then, when electrical equilibrium is obtained,

$$x = L \frac{r'}{r + r'} \text{ (in knots)}$$

$$y = L \frac{r}{r + r'} \text{ (in knots).}$$

Correction for Murray's Loop Method (*Hockin*).—This correction is seldom available, as the resistance of the fault, as well as of the insulation, must be known. But when these are known, the position of a fault with a resistance of a megohm or upwards can be ascertained very accurately.

The same figure as in the last.

Let L be the length of the cable.

z the distance of the fault from the centre of the cable, in knots.

r and r' the value of the adjustable resistance coils giving equilibrium.

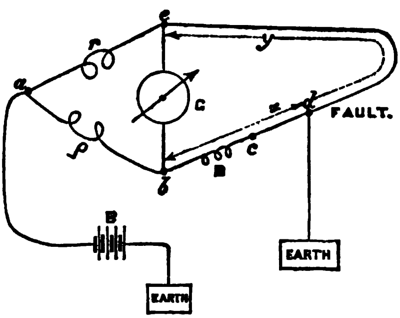
F, the known resistance of the fault in megohms; and

I, the resistance, in megohms, of the insulation of half the cable (supposed faultless).

Then

$$z = \frac{L}{2}\left(\frac{2F}{I} + 1\right)\frac{r' - r}{r' + r} \quad . \quad . \quad . \quad \text{knots.}$$

Varley's Loop Method. The cable end c is joined to an adjustable resistance, R; the end b of the latter and e of the cable are connected with the galvanometer, G, resistances r and ρ, and the battery, B, in the form of a Wheatstone's balance.



x and y are the resistances in ohms of the lengths of cable from the ends to the fault, the whole conductor having l ohms.

$$x = \frac{l\rho - Rr}{\rho + r} \text{ (ohms);}$$

$$y = (\mathrm{R} + l)\,\frac{r}{\rho + r} \text{ (ohms).}$$

If the cable be n knots long, the distance of the fault is

$$\frac{l\rho - \mathrm{R}r}{(\rho + r)\,n} \text{ knots from the end } c \text{, and therefore}$$

$$(\mathrm{R} + l)\,\frac{r}{(r + \rho)\,n} \text{ knots from the end } e.$$

When the branch resistances (r and ρ) are equal,

$$x = \frac{l - \mathrm{R}}{2}\,;\; y = \frac{l + \mathrm{R}}{2} \text{ (ohms)}$$

The distance of the fault from c is $= \dfrac{l - \mathrm{R}}{2\,n}$; and the distance of the fault from e is $= \dfrac{l + \mathrm{R}}{2\,n}$.

Corrections for loop-tests.—These formulæ are developed on the supposition that only one fault exists in the looped lines. This supposition is only fulfilled when the fault in question has a resistance either approximating to zero, or more generally, so small as to be neglected against the absolute insulation of the whole looped line. Now defective insulation acts as a fault at a certain point in every line, which fault has a resistance equal to the absolute insulation resistance of the line; and the position of such an apparent fault (which Schwendler calls the Resultant Fault) in a looped line can always be found by a loop-test in accordance with the foregoing rules when the lines are in their ordinary condition. Thus, a line on which communication is interrupted or imperfect has virtually two faults, the

position and resistance of one of which (that due to defective insulation) is known, and the other (that which causes interruption or imperfect communication) may be localized by the following formula :

$$x = (1 + d)\,\frac{(\rho\, l - r\,\mathrm{R})}{r + \rho} - d\,y.$$

In which x is the resistance from the testing station to the fault, d the proportion between the resistances of the two faults, *i.e.*, the resistance of the fault to be localized divided by the absolute insulation resistance, l the conductor resistance of the looped line, y the resistance of the line from the testing station to the apparent fault which is produced by defective insulation, all other terms in the formula having the same meaning as before.

In most cases, when the line consists of wire of the same gauge, y will be found equal to $\frac{l}{2}$, and if the test be taken with equal branches in the bridge,

$$x = \frac{l - \mathrm{R}\,(1 + d)}{2}.$$

Another correction for loop-test (*H. A. Taylor*).

a F f b

Let F = *apparent* position of fault by loop-test.

A = *distance a* to F obtained by loop-test in knots.

B = " *b* to F " " "

f = true position of fault.

F to f = x = distance, in knots, of true from apparent position.

P = resistance, in megohms, of cable when perfect.

Q = resistance, in megohms, of cable when faulty.

$$x = \frac{Q\,(A - B)}{2\,(P - Q)}$$

The true position of the fault is of course further from the centre of the cable than the apparent position.

If the true distance of fault from *end of cable* = d,

$$d = \tfrac{1}{2}\left\{ (A + B) - (A - B)\frac{P}{P - Q} \right\}$$

If A and B are expressed in units, $(A - B)$ = the resistance unplugged to produce equilibrium in the loop-test; and $(A + B)$ = the total copper resistance of the cable, in which case d will be in units also.

Resultant fault in an insulated wire.—Mr. W. Schwendler suggested a method of testing cables during their manufacture by means of Murray's loop-test, on the principle, that so long as a cable remained electrically perfect throughout, the leakage through the insulation would make the apparent resultant fault appear to be in the middle; but that if even a very small fault were developed, the apparent *resultant fault* would no longer be in the middle, but be shifted more or less towards one end, according to the magnitude of the injury.

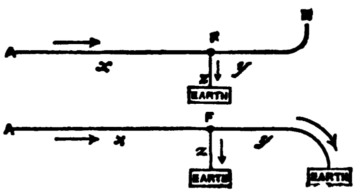
Unfortunately, in practice, the gutta-percha cores are sent to the machines new, and the last lengths joined on are worse insulated than those which have been made some time, so that a cable during manufacture is never homogeneous, and the resultant fault therefore does not, or should not lie in the middle, but towards the end which is being covered.

If the cable-ends, during manufacture, be connected up

in a circuit of the loop-test, and the galvanometer needle when deflected make contact as a relay, a bell may be sounded in the event of a fault occurring, and the manufacture stopped.

FAULTS IN SUBMERGED CABLES.

When the cable is submerged and only one end is to be had, its resistance R is measured when the farther end is insulated and the resistance r when it is to earth. This can, of course, only be done when the fault is not so great as to entirely prevent communication, or, when by pre-arrangement the operator of the distant station knows when to put his end to earth, and when to insulate it.



Let $l = x + y$ the whole copper resistance of the cable, before the appearance of the fault; the resistance of the fault being $= z$.

$$x = r - \sqrt[2]{(R - r)(l - r)} \text{ (ohms)}$$

$$y = (l - r) + \sqrt[2]{(R - r)(l - r)} \text{ (ohms)}$$

$$z = (R - r) + \sqrt{(R - r)(l - r)} \text{ (ohms)}$$

If a knot of conductor have a resistance of n ohms,

Distance of fault from A

$$= \frac{1}{n}\left[r - \sqrt[2]{(R - r)(l - r)}\right] \text{ (knots)}$$

Distance of fault from B

$$= \frac{1}{n}\left[(l - r) + \sqrt[2]{(R - r)(l - r)}\right] \text{ (knots)}$$

When, however, the fault is so great that the necessary signals cannot be transmitted to instruct the operator at the further end when to put the cable to earth, and when to insulate it, the home end is either left insulated or arrangements are made to have it insulated and "earthed" at certain agreed periods. The ship then crosses to the other end, where measurements are made, and similar ones are also made at the home end.

From the two measurements with the distant ends insulated,

$$1.)\ R = x + z \text{ (ohms)}$$

$$2.)\ R' = z + y, \text{ (ohms)}$$

and we have

$$x = \frac{R - R'}{2} + \frac{l}{2} \text{ (ohms)}$$

$$y = \frac{R' - R}{2} + \frac{l}{2} \text{ (ohms)}$$

$$\text{Distance of fault from A} = \frac{R - R' + l}{2n} \text{ (knots).}$$

$$\text{Distance of fault from B} = \frac{R' - R + l}{2n} \text{ (knots).}$$

From the two measurements with distant ends "earthed,"

$$1.\ r = x + \frac{yz}{y + z},$$

$$2.\ r' = y + \frac{x z}{x + z}.$$

in ohms,—

$$x = \frac{r(l - r')}{r - r'}\left[1 - \sqrt{\frac{r'(l - r)}{r(l - r')}}\right]$$

$$y = \frac{r'(l - r)}{r' - r}\left[1 - \sqrt{\frac{r(l - r')}{r'(l - r)}}\right]$$

and in knots,—

$$\text{Length } x = \frac{r'(l - r')}{n(r - r')}\left[1 - \sqrt{\frac{r'(l - r)}{r(l - r')}}\right]$$

$$\text{Length } y = \frac{r'(l - r)}{n(r' - r)}\left[1 - \sqrt{\frac{r(l - r')}{r'(l - r)}}.\right]$$

Resistance of fault.—When a cable having a known insulation resistance, R megohms, has a fault in it which reduces its resistance to r megohms; the resistance of the fault is

$$z = \frac{R r}{R - r} \quad . \quad . \quad . \quad \text{megohms.}$$

Distance of fault by tension (*Clark*).—Let the line make complete earth at the fault. R is a resistance in ohms inserted between the home end of the line and one pole of a battery of galvanic elements whose other pole is to earth. T is the tension of one end, and t that of the other end of the resistance, R.

Then

$$T - t : R :: t : x;$$

whence

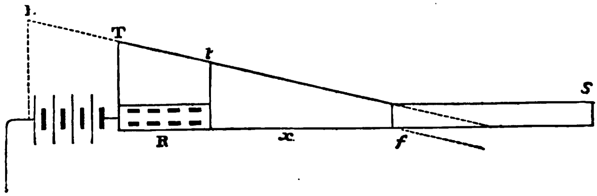
$$x = \frac{t R}{T - t} \text{ ohms;}$$

and, if the line has n ohms per statute mile, the distance d of the fault is

$$d = \frac{R}{n} \cdot \frac{t}{T - t} \text{ (statute miles).}$$

The tensions, T and t, are measured with an electrometer. When $t = \frac{1}{2}$ T, which may easily be obtained by adjusting R, then x = R.

The same where the fault makes partial earth.—



The battery, B, is inserted between earth and a resistance coil, R ohms, which is connected with one end of the faulty cable, whose other end, S, is insulated. The tensions of the two ends of R are T and t, and that at the further end of the cable is S.

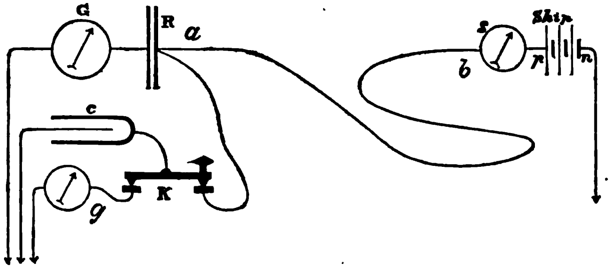
Then the cable resistance, x, between the fault and the end of R, is

$$x = \frac{(t - S)\,R}{T - t} \text{ (ohms).}$$

During the laying of the Atlantic Cable these tensions were observed on shore every five minutes by the discharge of a condenser, and their value telegraphed to the ship.

Method of continuous testing.—This system, which is due to Mr. Willoughby Smith, was first employed in 1866, during the laying of the Atlantic line.

The end, *a*, of the cable on shore is connected with a very great resistance, R, and with the front contact of a manipulating key, K.



The resistance, R, which may be of selenium or of gutta-percha, has a resistance of 20 to 30 million ohms; its further end is connected (through the mirror galvanometer G) to earth. A condenser, *c*, is inserted between the lever of the key and earth.

On the ship, the end, *b*, of the cable is connected permanently with a mirror galvanometer, *s*, and battery of 100 cells to earth. The current of this battery causes a steady deflection of *s*, due principally to the leakage through the insulation, and of G (on shore), due to the passage of the current through R (which is equal to about 10 or 15 miles of cable insulation). This deflection is observed and recorded every 5 minutes.

Continuity is observed on shore by the ship changing the direction of the current every 15 minutes, which causes the deflection of G to be reversed.

Insulation on board is measured by the deflection of *s*; the resistance of R being too great to interfere with the result. *Insulation* on shore is observed by measuring the

tension at R. This is done every 5 minutes by measuring the discharge from *c*. The key is pressed down for 10 seconds, putting *c* to line; it is then let go, and the discharge measured upon the mirror galvanometer, *g*. The result is communicated to the ship. In the event of a fault occurring, its distance is calculated by the method given above.

Speaking through the cable without interfering with the insulation test is done by making R in the form of a condenser, and by inserting a similar condenser between the end, *b*, and galvanometer, *s*. Then if either ship or shore charge the outside plates with + or − electricity, a corresponding impulse will be transmitted through the cable, and be indicated upon the galvanometer, although no electricity really enters or leaves the cable. By making the slight sudden deflections which are thus produced to the right hand and left hand represent respectively dots and dashes, a continued and speedy correspondence may be kept up during the testing.

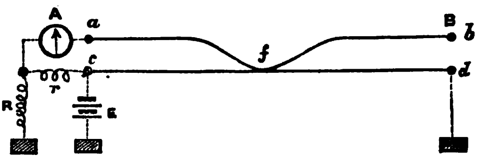
Exposure of Copper at Fault.

When the copper conductor of a cable is laid bare at a fault, if a positive current be sent through, the exposed copper will become oxydised and coated with copper salts. If a negative current be then sent through, those salts will be reduced, and afterwards hydrogen evolved at the fault. It is found useful, in measuring the copper resistance of the injured cable, to avoid the polarization currents of both the copper salts and the hydrogen, by observing the resistance in the moment between the

disappearance of the salts and the evolution of the hydrogen. For this purpose the operator polarizes the fault by a copper current of some minutes' duration, and then commences his measurement with a zinc current of rather less strength. As the zinc current reduces the copper oxide and salts away from the fault, and the cause of polarization current is thus removed, the apparent resistance gradually increases until the first formation of hydrogen, which will cause a sudden and considerable increase. The resistance observed immediately before this sudden increase is the nearest approximation to the true copper resistance of the faulty piece of cable.

FAULTS IN LINE WIRES.

To find contact between two over-head wires.—



Let the two overland lines, *a b* and *c d*, touch each other at the point *f*, somewhere between the stations A and B. Let the further end, *b*, of one of the lines be insulated, and the further end, *d*, of the other be put to earth. Connect a galvanic battery, E, between earth and the home end, *c*, of the line *c d*. Then insert a galvanoscope and adjustable resistance, R, between the home end, *a*, of line *a b*, and earth, and between the junction of the galvanoscope with R and the end *c* of line *c d* insert a

known resistance r ohms. When the galvanoscope needle is balanced we have the proportion

$$\frac{c\,f}{f\,d} = \frac{r}{R},$$

and if the whole length, $c\,d$, is known, the distance of the fault, $c\,f$, from the end, c, is

$$c\,f = c\,d \times \frac{r}{R + r}.$$

To Localise a Contact between two Wires (*Schwendler*).

1. Insulate the further ends, and measure the resistance of the two wires as a loop = R ohms.

2. Connect the further ends, and measure the resistance as before = r ohms.

The distance, x, of the contact from the testing station is

$$x = \frac{r - \sqrt{(L\,m + L'\,m' - r)\,(R - r)}}{m + m'} \quad . \; . \text{ statute miles}$$

in which

L = the length, in statute miles, of one of the lines.
m = its resistance per statute mile.
L′ = the length of the other line.
m' = its resistance per mile.

Example.—Two lines (A and B), each 200 miles long, are supported upon the same posts, and are somewhere in contact. (A) is of No. 1 wire, the resistance (m) of which is 4 ohms per mile; the other (B) is of No. 3 wire, which has 6·6 ohms per mile. Therefore

$$L\,m = 200 \times 4 = 800; \text{ and}$$
$$L'\,m' = 200 \times 6{\cdot}6 = 1320 \text{ ohms.}$$

When measured with the further ends insulated, the combined

resistance was 2400 ohms; and when connected it was only 2050 ohms. Therefore the distance (x) of the fault was

$$x = \frac{2050 - \sqrt{(800 + 1320 - 2050)(2400 - 2050)}}{4 + 6\cdot6}$$

$$= \frac{2050 - 156\cdot8}{10\cdot6} = \frac{1893\cdot2}{10\cdot6} = 178\cdot6 \text{ miles.}$$

When the wires are of the same gauge

$$x = \frac{r - \sqrt{(2\,L\,m - r)(R - r)}}{2\,m} \text{ miles.}$$

When the two measurements (R and r) **are equal** *to each other.*

1. If the wires have different gauges

$$x = \frac{R}{m + m'}, \quad . \quad . \quad . \quad \text{miles.}$$

2. If the wires are of the same gauge

$$x = \frac{R}{2\,m} \quad . \quad . \quad . \quad \text{miles.}$$

Contacts between Line-wires (*Culley*).

1. When the contact is without resistance, measure the resistance of the loop formed by the two wires. Half this loop resistance, divided by the known resistance per mile of the wire, will give the distance of the fault.

2. When the contact is imperfect, that is to say, has resistance, it is better to employ one of the wires between the station and the fault as a leading wire only, insulating its further end; and using the second wire for measuring. If the two wires be A and B, insulate the further end of A, and connect its near end to the zinc pole of a battery. Connect the copper pole with the

middle of a differential galvanometer. Then connect one coil of the galvanometer to the near end of B; the other coil to earth; and the distant end of B to earth. If the needle is balanced the fault is in the middle of the line; if not, add resistance to one side of the galvanometer until it is balanced. Then if R ohms be the added resistance, and L ohms the original resistance of B, the length between the station and fault has

$$r = \frac{L - R}{2} \text{ ohms,}$$

and the distance, D, of the fault is

$$D = \frac{L - R}{2 r_1} \text{ miles,}$$

r_1 being the average resistance, in ohms per mile, of the wire.

Contact between a Wire and Earth.

1. When the contact to earth is very good, the resistance of the section between the station and fault gives he distance of the contact.

2. When the fault has resistance, its distance may oe determined with the aid of a second good wire by Murray's loop-test (see page 41). The distant ends ot the two wires are joined together. Let L be the original resistance of the faulty line; L′ that of the good wire; R and R′ the proportions of the testing resistances; then the resistance, x, to the fault is

$$x = R \cdot \frac{L + L'}{R + R'}$$

3. When no second wire is to be had, the distance of

the fault must be found by measuring the resistance when the distant end is to earth, and when it is insulated, the original resistance of the line being known. See page 47.

Corrected Resistance of Line (*Schwendler*).

R = the measured insulation resistance of line.

r = wire resistance (*without* relay at distant end) measured.

r' = wire resistance (*with* relay at distant end) measured.

1.) **The corrected line wire resistance** (L) is

$$L = 2\left(R - \sqrt{R(R - r)}\right)$$

2.) **The corrected insulation resistance** (R′) is

$$R' = \sqrt{R(R - r)}$$

3.) **The relay resistance** (r'') at the distant station is

$$r'' = \frac{R(r' - r)}{R - r'}$$

Wires of different gauges.—When a line consists of two gauges of wire of the same conducting power, the two diameters being d and d', and the lengths of the different wires, l and l', if R is the whole measured resistance, the average resistance per mile, r, of the one gauge is

$$r = \frac{d'^2}{l\,d'^2 + l'\,d^2} R$$

and that of the other gauge

$$r' = \frac{d^2}{l\,d'^2 + l'\,d^2} R.$$

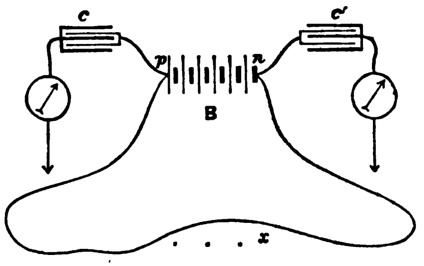
Faults in short lengths of insulated wire (*Clark*).—Minute faults in short lengths are found by connecting a

powerful battery to one end, and drawing wire slowly through a basin of water or wet sponge insulated by suspension on gutta-percha cords. A Peltier or Milner electrometer is connected with the basin, and renders any leakage apparent. Even the most perfect wires give a visible leakage on the electrometer, and it is sometimes therefore necessary to make some imperfect connection with the basin by a piece of wood or a wet thread, sufficient to reduce the normal leakage of the wire to a moderate degree of deflection, and any change in this is at once apparent. If the fault be very large, a galvanometer will suffice to indicate it. A coil of a mile of wire wound on a drum, and insulated, may be treated in this way on an insulated stand, and gradually unwound; the electrometer being connected to the drum, and also a high resistance. As long as the fault is on the drum, the electrometer will be deflected, but as soon as it is unwound the deflection will fall.

Warren's Method.—This is a somewhat similar, but superior arrangement. The coil of wire is wound on to two separate drums, both insulated, and an electrometer connected to each. A powerful battery is connected to one end of the conductor; the induction and leakage through the dielectric causing each of the electrometers to become deflected. Both drums are now discharged by touching them with the hand, and the electrometers fall to zero. The drum which has a defect on it, soon, however, acquires its tension again, and its electrometer is deflected, the other remaining

unaffected. More wire is then unwound, till the fault appears on the other drum. The outside of the wire between the drums must be wiped very dry, the other parts should be moist.

Accumulation test (*Clark*, 1860).—A method for locating a minute fault in an otherwise perfect cable



during manufacture. The two ends of the cable are connected with the two poles of a large battery, B. Two condensers, C and C′, are connected with the opposite poles of the battery. The fault (x) not being in the middle of the cable, the tensions of the charges of C and C′ will be as the lengths between the ends of the cable and the fault, or

$$C : C' :: p\,x : n\,x.$$

Or if L is the whole length of the faulty wire in yards, the distance of the fault

$$\text{from end } p = L \, . \, \frac{C}{C + C'} \text{ yards;}$$

$$\text{from end } n = L \, . \, \frac{C'}{C + C'} \text{ yards.}$$

The usual arrangements must be made for measuring the

discharges of the two condensers. If a single galvanometer be used, a commutator will be necessary to invert the coils, so as to get the two deflections on the same side of zero, as the one charge is positive and the other negative.

Rupture of conductor.—When the conductor of an otherwise perfect cable is severed, the distance of the fault may be found by ascertaining the electro-static capacity of the cable from the testing station to the fault by any of the methods given further on.

Let the capacity of the cable be f microfarads per knot: that of the severed portion, F microfarads; the distance, D, is

$$D = \frac{F}{f} \quad . \quad . \quad . \quad \text{knots.}$$

To test leading wires.—When three or more leading or cable wires end near together, their several conducting resistances may be measured as follows:—

Let the wires be A, B, and C. Connect the further ends of the wires together alternately, and measure their combined copper resistance. Let the resistance of

$$\begin{aligned} &\text{A and B be} = r \ \text{ohms,} \\ &\text{A} \ \ ,, \ \ \text{C} \ ,, \ = r_{\prime} \ \ ,, \\ &\text{B} \ \ ,, \ \ \text{C} \ ,, \ = r_{\prime\prime} \ \ ,, \end{aligned}$$

The resistance of $A = \dfrac{r + r_{\prime} - r_{\prime\prime}}{2}$ ohms.

,, $B = \dfrac{r + r_{\prime\prime} - r_{\prime}}{2}$ ohms.

,, $C = \dfrac{r_{\prime\prime} + r_{\prime} - r}{2}$ ohms.

Determination of Capacity in Absolute Measure.

The electro-static capacity of the cable may be measured by means of resistances without comparison with a standard condenser. For this test it is first of all necessary to find by experiment what resistance, R, in megohms, would be required to produce, with the same battery used to charge the cable, the unit deflection.

The unit deflection with a mirror galvanometer is one division of the scale.

The unit deflection of a tangent galvanometer is ~~90°~~ 45° (because tan ~~90°~~ 45° = 1).

The unit deflection of a sine galvanometer is ~~45°~~ 90° (because sine ~~45°~~ 90° = 1).

When the value of R has been ascertained, it is necessary to know the time, t seconds, which the needle occupies in making half a complete oscillation, which is found by setting the needle oscillating and counting the number of times it passes across the meridian in a minute or other observed interval of time.

Then charge the cable and observe the throw, $\alpha°$, of the needle. If α is read off in degrees, the electro-static capacity is

$$C = 2 \frac{t \sin \frac{\alpha}{2}}{\pi R} \quad . \quad . \quad . \quad \text{(microfarads)};$$

or,

$$C = \cdot 6366 \frac{t \sin \frac{\alpha}{2}}{R} \quad . \quad . \quad \text{(microfarads)}.$$

If a is read off in divisions of the mirror galvanometer scale,

$$C = \frac{\cdot 3183\, a\, t}{R}, \quad . \quad . \quad . \quad \text{(microfarads).}$$

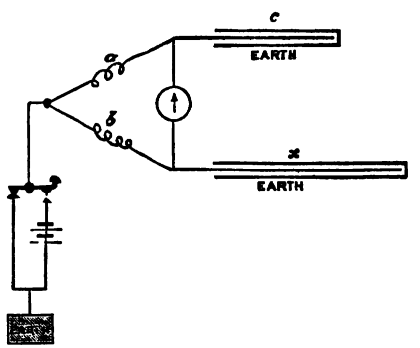
Example.—In the determination of the electro-static capacity of a condenser for the British Association Committee, it was found that with a mirror galvanometer the unit deflection was produced by a given battery power with a resistance $R = 5{\cdot}16 \times 10^3$ megohms; the value of t was $9{\cdot}37$ seconds; and the throw, $a°$, was $168{\cdot}5$ divisions. Therefore

$$C = \frac{\cdot 3183 \times 168{\cdot}5 \times 9{\cdot}57}{5{\cdot}16 \times 10^3} = \cdot 09948 \text{ (microfarads).}$$

The value of R for the above formula may be found by either of the methods given at pages 86 and 87.

Comparison of Electro-static Capacities.

1. **De Sauty's Method.**—The resistances a and b, in ohms; the condenser, c, of known capacity, expressed in microfarads or knots' length of cable, and the cable



x, are arranged with galvanometer and battery in the form of a Wheatstone's balance, the point of junction on

the right-hand side being formed by the earth to which the outsides of cable and condenser are connected.

Let a and b (the two wire resistances) be adjusted until, on pressing down the contact, no deflection is observed at the galvanometer.

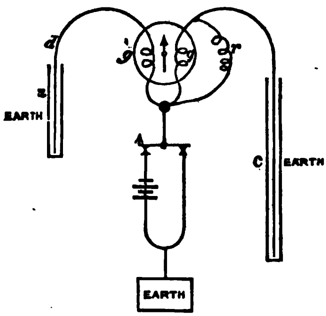
c and x are the electro-static capacities of the condenser and cable respectively. Then

$$\frac{a}{b} = \frac{x}{c},$$

or

$$x = c\frac{a}{b}$$

2. **Varley's Method.**—The coils g' and g of a differential galvanometer are connected at one end together to



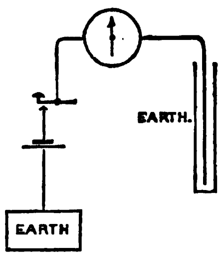
the key and battery; their other ends to the standard condenser c and cable x respectively. A shunt is used across the coil g. The initial magnetic effect of the coil g upon the needle is m, that of g' is m'. Then

$$x = c\frac{m'}{m}\left(\frac{g}{r} + 1\right).$$

If the galvanometer coils are equal ($m = m'$)

$$x = C\left(\frac{g}{r} + 1\right).$$

3. **Method of Swing of Needle.**—The cable whose capacity is x microfarads is connected with a galvanometer, and through a contact key with battery and



earth. On making contact the needle is deflected α°. The cable is removed, and a standard condenser whose capacity is C microfarads is introduced instead, giving a throw of α_1°. Then

$$x = C \frac{\sin \frac{\alpha}{2}}{\sin \frac{\alpha_1}{2}} \text{ microfarads.}$$

If in each case a different shunt is used, let the resistance of the galvanometer be g ohms; that of the shunt, when the deflection α with the cable is obtained, be s ohms; and when the deflection α_1 with the standard condenser be s_1, then

$$x = C \frac{\sin \frac{\alpha}{2} \cdot \frac{g+s}{s}}{\sin \frac{\alpha_1}{2} \cdot \frac{g+s_1}{s_1}} \quad . \quad . \quad . \quad \text{(microfarads).}$$

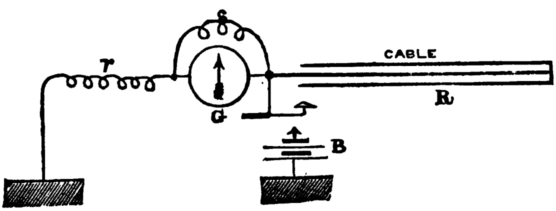
If the shunt is used with the cable, and not with the condenser,

$$x = C \cdot \frac{\sin \frac{a}{2} \cdot \frac{g+s}{s}}{\sin \frac{a_1}{2}} \quad . \quad . \quad . \quad \text{(microfarads).}$$

Inductive capacity from insulation and fall of tension (*Siemens*).*

$$\text{Inductive capacity} = \frac{t \times \cdot 4343}{R(\log C - \log c)} \quad \text{(microfarads).}$$

Where R = resistance of insulation, in megohms; C = immediate discharge; c = discharge after t seconds; t = interval of time in seconds.



When the cable is very long a resistance, r megohms, is inserted between galvanometer and earth. Key is depressed for T minutes, and deflection, d, observed. Then key is raised, and after t minutes deflection d' observed.

$$\text{Inductive capacity} = \frac{\cdot 4343\left(R + r + \frac{sg}{s+g}\right)t}{R\left(r + \frac{sg}{s+g}\right)\log \frac{d}{d'}} \quad . \quad . \quad \text{microfarads.}$$

* Submarine Telegraph Report, 1861, p. 457.

R = resistance of insulation after T minutes; s resistance of shunt in ohms; g resistance of galvanometer in ohms.

The joint tension of two condensers or cables, when one is charged by another, is as follows:

Let C = capacity of the charged condenser; T = its tension; c = capacity of other condenser; t = the tension when they are united.

Then $$t = T \times \frac{C}{C + c}$$

The joint electro-static capacity of two cables.—If a charged cable or condenser be joined to another cable, the charge will divide itself between the two in proportion to their respective capacities, the resulting tension being the same in both. Let C be the capacity of a standard condenser, charged to tension T, c that of another condenser or cable, and t their joint tension when combined.

Then $$t : T :: C : c + C.$$

And the capacity of the second condenser will be

$$c = \frac{T - t}{t} C.$$

The electro-static capacity, F, of a knot of cable being given in microfarads, its specific capacity, k', is

$$k' = F \frac{\log D - \log d}{2{\cdot}728} \quad . \quad . \quad . \quad \text{microfarads.}$$

The specific capacity is thus measured in terms of that of a cube knot of the insulator.

Approximate Electro-static Capacities of various Insulators.

Insulator.	Electro-static Capacity (k) of a plate 1 square foot × $\frac{1}{1000}$ inch.	Air = 1.
	Microfarads.	
Air . .	0·0323	1·00
Resin .	0·0572	1·77
Pitch .	0·0581	1·80
Beeswax	0·0601	1·86
Glass .	0·0614	1·90
Sulphur .	0·0623	1·93
Shellac .	0·0630	1·95
I. R. .	0·0904	2·8
Hooper .	0·1073	3·1
G. P. .	0·1357	4·2
Mica .	0·1620	5·0

The electro-static capacity of an insulated cylindrical conductor is

$$K = 1{\cdot}384\, k \frac{l}{\log \frac{D}{d}} \quad . \quad . \quad \text{microfarads.}$$

In which

k = the capacity of a plate 1 square foot × 1 mil.

l = the length in knots.

$$\left.\begin{array}{l} D = \text{the outer and} \\ d = \text{the inner} \end{array}\right\} \text{diameter of the cylinder.}$$

The electro-static capacity (k) **of a plate** 1 *square foot surface, and* 1 *mil thick, is*

$$k = 0{\cdot}7225 \;.\; K \;.\; \log \frac{D}{d} \quad . \quad . \quad . \quad \text{microfarads.}$$

In which

K = the electro-static capacity of 1 knot of cable.

D = diameter of insulator.

d = diameter of conductor.

The electro-static capacity of a cube knot *is*

$$k' = 0{\cdot}3666 \text{ K} \log \frac{\text{D}}{d} \quad . \quad . \quad . \quad \text{microfarads,}$$

K being, as before, the measured capacity of 1 knot length of cable.

The electro-static capacity (K′) **of a plate** whose surface is q square feet, and thickness is m mils, is

$$\text{K}' = k \frac{q}{m} \quad . \quad . \quad . \quad \text{microfarads,}$$

k being the capacity of a plate of the same material 1 square foot surface and 1 mil thick.

Resistance and Induction of Insulators.—The product of the resistance, in megohms, and the electro-static capacity, in microfarads, of any insulator, is a constant value, independent both of dimensions and form; and dependent only upon the nature of the material.

Thus the product of the insulation resistance, and the inductive capacity of a coated sheet of ordinary gutta-percha of any size, is equal to the product of the insulation resistance at the same temperature, and inductive capacity of a knot, or any other length of cable core covered with the same material.

This becomes evident by the following considerations:

$$\text{R} = r \log_e \frac{\text{D}}{d} \cdot \frac{1}{2 \pi l} \cdot \text{megohms,}$$

and

$$\text{F} = \frac{f}{\log_e \frac{\text{D}}{d}} \cdot 2 \pi l \cdot \text{microfarads;}$$

therefore

$$\text{R F} = r f$$

where R = the measured resistance, *r* the specific resistance of the material, F the measured electro-static capacity, and *f* the specific electro-static capacity of the material.

ACCUMULATORS OR CONDENSERS.

Accumulators (or, as they are commonly called, condensers) are used for comparing the electro-static capacities of cables, the electro-motive forces of batteries, for joint-testing, and for preventing earth-currents in submerged cables.

Varley's condensers are made of alternate sheets of very thin (silver) paper saturated with paraffin, and tin-foil.

Clark's condensers are made with tin-foil and sheets of thin mica coated with paraffin or shell-lac.

W. Smith's condensers are insulated with sheets of specially prepared gutta-percha containing a large proportion of shellac.

When a condenser is first made, and before it has been charged with electricity, if one pole be connected with earth, the other side being insulated, the latter will be found charged with positive electricity. To avoid error arising from this cause, it is advisable to leave the terminals of a condenser connected by a short circuit whenever it is not in use.

The electro-static capacities of condensers are expressed in microfarads.

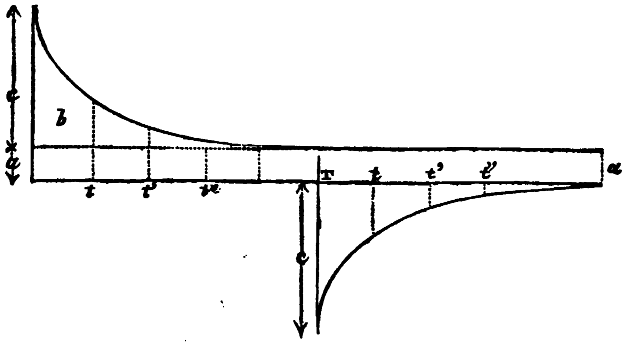
NOTES ON ELECTRIFICATION.

When an insulated wire or cable is connected to a battery, and the deflection noted on a galvanometer, the first rush of current into the cable is due to the electro-static capacity of the insulator. Battery contact being still maintained, the deflection falls very rapidly at first, and gradually becomes reduced for some time after. The shorter the length of cable, and the higher the degree of insulation, the less defined will be the differences in the deflections after a few minutes' contact.

The first current is due to three causes: 1st, the electro-static charge between the interior and exterior surfaces; 2nd, the leakage or conduction of the insulating material; and, 3rd, the current due to electrification or absorption. The first is speedily completed, the second remains constant, and is permanent, whilst the electrification diminishes in a rapid ratio, and at length ceases entirely.

Calling the permanent current due to conduction, a, that due to electrification or absorption, b, the observed current at any time, t, will be $a + b$. If, after a time, T, when b has become so small that it may be neglected, we remove the battery and put the cable to earth, the electrification charge will flow out of the cable with diminishing force, and the curve representing the current at intervals t, t', t'', after the cable is put to earth, will be equal to that at the times, t, t', t'', after the first application of the battery, but in the opposite direction, so that we may deduce the value of the currents entering

the cable at any time, t', after the application of the battery, by adding the constant value, a, to the current flowing out of the cable at a similar interval of time, t',



after putting the cable to earth. The current at the first contact with the battery will therefore be equal to $a + c$.

In these experiments the best results are obtained on a galvanometer, without a damper attached to the needle. A shunt capable of being easily inserted between the galvanometer terminals, and removed without interfering with the experiments, is required.

The short circuit plug being removed, contact is made between the battery and cable through the galvanometer, and the deflection carefully noted. The short circuit plug being replaced, the shunt is removed, and the deflection noted at the end of one, two, three, &c., minutes.

Great care must be taken that the cable has not been previously charged, and the battery must be in very good condition. Unsteady deflections must be totally discarded.

The ratio between the deflections for equal periods of

contact is independent of the length and is greater or less according to the specific resistance of the dielectric.

The ratio is unaltered under different electro-motive forces so long as constancy is maintained during the time of observation.

According to Mr. Warren's tests, the rate of electrification of india-rubber appears to be independent of its temperature: that is to say, that if the current flowing into a cable at the end of one minute is C, and at the end of t minutes it is C_t; then at any other temperature the current with the same battery will be C', and that after t minutes C_t'; and that

$$C : C_t = C' : C_t'$$

This is, however, not the case with any other insulating material that we have met with. The rate of electrification, for instance, of gutta-percha when cold is much more rapid than when warm. The percentage increment of resistance between one minute, ten minutes, and one hour of a coil of French Atlantic core was as follows:—

Temperature 0°C.	Resistance after	1 min.	=	100
	Ditto „	10 min.	=	191
	Ditto „	1 hour	=	289
Temperature 12°C.	Resistance after	1 min.	=	100
	Ditto „	10 min.	=	136
	Ditto „	1 hour	=	167
Temperature 24°C.	Resistance after	1 min.	=	100
	Ditto „	10 min.	=	128
	Ditto „	1 hour	=	138

Coils having the same dimensions have rarely the same ratio in their resistances on prolonged contact with a battery, but when several coils are joined together, the ratio between the deflections for any two successive durations of contact will be the mean of that of the several coils. This result of electrification may be of important application in ascertaining whether any slight defects have occurred in manufacturing core into cable.

RATES OF WORKING THROUGH CABLES.

The rates of working with the same transmitting and receiving system, through two cables insulated with the same material, may be compared when their dimensions are known.

Let S and S_1 be the speeds of working,
l and l_1 the lengths of the lines,
D and D_1 the diameters of the insulators,
d and d_1 the diameters of the conductors,

then

$$\frac{S_1}{S} = \frac{d_1^2\, l^2 \log \frac{D_1}{d_1}}{d^2\, l_1^2 \log \frac{D}{d}}.$$

If the rate S is known for one of them, the rate of working through the other will be

$$S_1 = S\,\frac{d_1^2\, l^2 \log \frac{D_1}{d_1}}{d^2\, l_1^2 \log \frac{D}{d}}.$$

If they are only different lengths of the same cable,

$$S_1 = S\left(\frac{l}{l_1}\right)^2.$$

If the lengths are the same, but the cables differ in their other dimensions,

$$S_1 = S\,\frac{d_1^2 \log \frac{D_1}{d_1}}{d^2 \log \frac{D}{d}}.$$

The rate of signalling (S) through a cable is expressed as follows:

$$S = c \cdot \frac{d^2 \log \frac{D}{d}}{l^2} \text{ words per minute.} \qquad (1.$$

in which c is an empirical constant.

Since the resistance, r, per knot, of the copper is

$$r = \frac{81361}{d^2}$$

$$d^2 = \frac{81361}{r} \quad . \; . \; . \; . \; . \; . \qquad (2.$$

and since the electro-static capacity, f, per knot of a gutta-percha cable is

$$f = \frac{\cdot 18769}{\log \frac{D}{d}}$$

$$\log \frac{D}{d} = \frac{\cdot 18769}{f} \quad . \; . \; . \; . \qquad (3.$$

We may insert (2 and (3 in (1, which gives the more convenient formula for the speed (S)

$$S = c \cdot \frac{81361}{r} \cdot \frac{\cdot 18769}{f} \cdot \frac{1}{l^2} = c\,\frac{15270}{r f l^2}$$

In the Atlantic Cable (1865) l = 1896 knots; r = 4·01 ohms (when submerged); f = 0·3535 microfarads; the maximum speed which has been attained is 25 words a minute,

$$4{\cdot}10 \times 0{\cdot}3535 \times 1896^2 = 5210000$$

therefore the constant (c)

$$c = 25 \times \frac{5210000}{15270} = 8530.$$

Therefore, according to these data, the ***maximum*** speed (S) of any cable is

$$S = 8530 \times \frac{15270}{r f l^2} \quad . \; . \quad \text{words per minute}$$

$$= \frac{130{,}000{,}000}{r f l^2}$$

If we call the copper resistance of the whole length of any cable $r\,l$ = R ohms; and the whole electro-static capacity $f\,l$ = F microfarads; then R F = $r f l^2$; and

$$\text{speed} = \frac{130{,}000{,}000}{\text{R F}} \text{ words per minute,}$$

whatever the material of the cable.

Calculated by this formula, the speed of the British Indian Cable is 12 words per minute, whereas 15 words have been attained: therefore the constant 130 millions becomes 160 millions, and the *maximum* speed (S) at present attained is

$$S = \frac{160 \text{ millions}}{\text{R F}} \quad . \; . \; . \quad \text{words per minute;}$$

which is applicable for any cable, and any material.

The speed of working through a cable insulated with gutta-percha is as follows:—

1. With reflecting galvanometer

$$8530 \frac{d^2 (\log D - \log d)}{l^2} \quad . \quad . \quad \text{words per minute.}$$

2. With Morse

$$518 \frac{d^2 (\log D - \log d)}{l^2} \quad . \quad . \quad \text{words per minute.}$$

l being the length of the cable in knots,

D the diameter of the G. P. in mils or thousandths of an inch, and

d that of the copper in mils.

The speed of signalling through any core of Hooper's material with the reflecting galvanometer is about

$$11{,}557 \frac{d^2 (\log D - \log d)}{l^2} \text{ words per minute;}$$

and with Morse's apparatus

$$700 \frac{d^2 (\log D - \log d)}{l^2} \text{ words per minute,}$$

l being the length of the cable in knots,
D the diameter of the core, and
d that of the conductor, both in mils.

Tables of Speeds with Mirror System.

The following Tables are calculated from the data supplied by the Atlantic (1866) Cable, taking the working speed at 17 words per minute. The maximum speed attained experimentally with this cable was 25 words, or 50% higher than the working speed.

Working Speed* with Mirror System.

Gutta-percha and Copper strand—Equal weights.

$$\left(\frac{D}{d} = 2{\cdot}799\right)$$

Weights of		d in mils.	D in mils.	Speed of working in words per minute for following lengths.			
Copper strand.	Gutta-percha.			1000 knots.	1500 knots.	2000 knots.	2500 knots.
lbs.	lbs.						
100	100	84	235	18·3	8·1	4·6	2·9
110	110	88	246	20·1	8·8	5·0	3·2
120	120	92	257	22·0	9·7	5·5	3·5
130	130	96	268	24·0	10·6	6·0	3·8
140	140	99	278	26·0	11·4	6·5	4·2
150	150	103	288	27·5	12·2	6·9	4·4
160	160	106	297	29·3	13·0	7·3	4·7
170	170	109	306	31·1	13·8	7·8	5·0
180	180	113	315	33·0	14·7	8·2	5·3
190	190	116	324	35·0	15·5	8·7	5·6
200	200	119	332	37·0	16·4	9·2	5·9
210	210	122	340	38·4	17·0	9·6	6·1
220	220	124	348	40·3	17·9	10·1	6·4
230	230	127	356	42·1	18·7	10·5	6·7
240	240	130	364	44·0	19·5	11·0	7·0
250	250	133	371	46·0	20·4	11·2	7·4
260	260	135	379	48·0	21·3	12·0	7·7
270	270	138	386	49·4	21·9	12·3	7·9
280	280	140	393	51·2	22·7	12·8	8·2
290	290	143	400	53·1	23·6	13·3	8·5
300	300	145	407	55·0	24·4	14·0	8·8
310	310	148	413	57·0	25·3	14·2	9·1
320	320	150	420	59·0	26·2	15·0	9·4
330	330	152	427	60·4	26·8	15·1	9·7
340	340	155	433	62·2	27·6	15·5	10·0
350	350	157	439	64·1	28·5	16·0	10·3
360	360	159	446	66·0	29·3	16·5	10·6
370	370	161	452	68·0	30·2	17·0	10·9
380	380	164	458	70·0	31·1	17·5	11·2
390	390	166	464	71·4	31·7	17·9	11·4
400	400	168	470	73·2	32·5	18·3	11·7

* The maximum speed is 50% higher.

Working Speed* with Mirror System.

Gutta-percha 10% heavier than Copper strand.

$$\left(\frac{D}{d} = 2{\cdot}92\right)$$

Weights of		d in mils.	D in mils.	Speed of working in words per minute for following lengths.			
Copper strand.	Gutta-percha.			1000 knots.	1500 knots.	2000 knots.	2500 knots.
lbs.	lbs.						
100	110	84	245	19·0	8·4	4·8	3·0
110	121	88	257	21·0	9·3	5·3	3·4
120	132	92	268	23·0	10·2	5·8	3·7
130	143	96	279	25·0	11·1	6·3	4·0
140	154	99	290	27·0	12·0	6·8	4·3
150	165	103	300	28·4	12·6	7·1	4·5
160	176	106	310	30·4	13·5	7·6	4·9
170	187	109	319	32·3	14·3	8·1	5·2
180	198	113	329	34·2	15·2	8·6	5·5
190	209	116	338	36·1	16·0	9·0	5·8
200	220	119	346	38·0	16·9	9·5	6·1
210	231	122	355	40·0	17·8	10·0	6·4
220	242	124	363	42·0	18·6	10·5	6·7
230	253	127	371	44·0	19·5	11·0	7·0
240	264	130	379	46·0	20·4	11·5	7·4
250	275	133	387	48·0	21·3	12·0	7·7
260	286	135	395	49·4	21·9	12·4	7·9
270	297	138	402	51·3	22·8	12·8	8·2
280	308	140	410	53·2	23·5	13·4	8·5
290	319	143	417	55·1	24·5	13·8	8·8
300	330	145	424	57·0	25·3	14·3	9·1
310	341	148	431	59·0	26·2	14·8	9·4
320	352	150	438	61·0	27·1	15·3	9·8
330	363	152	445	63·0	28·0	15·8	10·1
340	374	155	451	65·0	28·9	16·3	10·4
350	385	157	458	67·0	29·7	16·8	10·7
360	396	159	465	68·4	30·4	17·1	10·9
370	407	161	471	70·3	31·2	17·6	11·2
380	418	164	477	72·2	32·1	18·1	11·6
390	429	166	484	74·1	32·9	18·5	11·9
400	440	168	490	76·0	33·7	19·0	12·2

* The maximum speed is 50% higher.

Working Speed* with Mirror System.

Gutta-percha 20% heavier than Copper strand.

$$\left(\frac{D}{d} = 3{\cdot}04\right)$$

Weights of		d in mils.	D in mils.	Speed of working in words per minute for following lengths.			
Copper strand.	Gutta-percha.			1000 knots.	1500 knots.	2000 knots.	2500 knots.
lbs.	lbs.						
100	120	84	254	20·0	8·9	5·0	3·2
110	132	88	267	22·0	9·8	5·5	3·5
120	144	92	279	24·0	10·7	6·0	3·8
130	156	96	290	26·0	11·5	6·5	4·2
140	168	99	301	28·0	12·4	7·0	4·5
150	180	103	312	30·0	13·3	7·5	4·8
160	192	106	322	32·0	14·2	8·0	5·1
170	204	109	332	33·5	14·9	8·4	5·4
180	216	113	341	35·5	15·8	8·9	5·7
190	228	116	351	37·4	16·6	9·3	6·0
200	240	119	360	39·4	17·5	9·9	6·3
210	252	122	369	41·4	18·4	10·4	6·6
220	264	124	377	43·3	19·2	10·8	6·9
230	276	127	386	45·3	20·1	11·3	7·2
240	288	130	394	47·3	21·0	11·8	7·6
250	300	133	402	49·3	21·9	12·3	7·9
260	312	135	410	51·2	22·7	12·8	8·2
270	324	138	418	53·2	23·6	13·3	8·5
280	336	140	426	55·2	24·5	13·8	8·8
290	348	143	433	57·1	25·4	14·3	9·1
300	360	145	441	59·1	26·2	14·8	9·5
310	372	148	448	61·1	27·1	15·3	9·8
320	384	150	455	63·0	28·0	15·8	10·1
330	396	152	462	65·0	28·9	16·3	10·4
340	408	155	469	67·0	29·7	16·8	10·7
350	420	157	476	69·0	30·6	17·3	11·0
360	432	159	483	71·0	31·5	17·8	11·4
370	444	161	490	73·0	32·4	18·3	11·7
380	456	164	496	75·0	33·3	18·8	12·0
390	468	166	503	77·0	34·2	19·3	12·3
400	480	168	509	79·0	35·1	19·8	12·6

* The maximum speed is 50% higher.

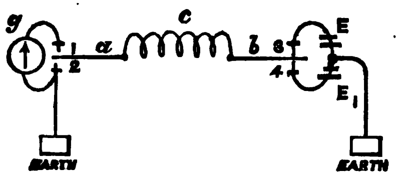
Table of actual Speeds attained in working through existing Cables.

CABLE AND SECTION.	Date of Exp.	Log $\frac{D}{d}$	Length in Knots.	Actual Speed in Words per Minute.	System.
1. RED SEA:—					
Suakin-Aden section	1860	0·5322	629	11	Morse
2. MALTA-ALEXANDRIA:—					
Malta—Tripoli	1861	0·4809	230	31	Morse
Tripoli—Bengazi	..	..	507	24	do.
Bengazi—Alexandria	..	..	597	17	do.
Alexandria—Malta	..	..	1330	3·2	do.
3. PERSIAN GULF:—					
Fao—Bussire	1864	0·5384	155	25	Morse
Bussire—Mussendom	..	..	329	17·5	do.
Mussendom—Gwadur	..	..	358	16·7	do.
Gwadur—Manora	..	..	266	20	do.
Fao—Mussendom	..	..	547	12·1	do.
Mussendom—Manora	..	..	624	9·64	do.
4. ATLANTIC CABLE (1865)	1867	0·5020	1896	17	Mirror
5. ATLANTIC CABLE (1866)	1867	0·5020	1857	17	Mirror
6. MALTA-ALEXANDRIA (1867)	1868	0·5107	925	19	Mirror
7. FRENCH ATLANTIC (1869):—					
Brest—St. Pierre	1869	0·4468	2584	15	Mirror
St. Pierre—Duxbury	..	0·5107	749	Any speed	do.

The following Table, extracted from a more detailed one by Sir W. Thomson, gives the relative speeds of working similar lengths of cables having different ratios $\frac{D}{d}$ when D is given.

$\frac{d}{D}$	$\frac{D}{d}$	Speed = $200\epsilon\left(\frac{d}{D}\right)^2 \log_\epsilon \frac{D}{d}$	$\frac{d}{D}$	$\frac{D}{d}$	Speed = $200\epsilon\left(\frac{d}{D}\right)^2 \log_\epsilon \frac{D}{d}$
0·1	10	·1252	0·6	1·66	·9996
0·2	5	·3500	0·6065	$1·649 = \sqrt{\epsilon}$	1·0000
0·3	3·33	·5891	0·7	1·429	·9554
0·4	2·5	·7971	0·8	1·25	·7764
0·5	2	·9421	0·9	1·111	·4684

Speed of Waves in Cables.—To measure the speed of waves in cables, it has been proposed to connect the cable (*c*), between the axes of the two synchronously oscillating tongues, *a* and *b*, which make contact at 1, 3, and 2, 4. E and E′ are equal batteries, their opposite poles



being connected with 3 and 4, and their point of junction to earth; *g* is a galvanometer connected between 1 and 2, the latter contact being to earth.

Let the velocity of *a* and *b* be adjusted to v oscillations per minute, until the needle of the galvanometer attains its maximum deflection. Then let the velocity be gradually diminished to v' oscillations per minute, the needle having passed zero, been deflected to its maximum on the other side, and returned to its previous maximum position. The number of waves n in the cable when the velocity is v, is

$$n = \frac{v}{v - v_1}.$$

And the time t which a wave takes to reach the further end is

$$t = \frac{1}{v - v_1} \text{ minutes.}$$

Instead of observing the two maximum deflections on the same side, the velocities at the moments when the needle makes alternate returns to the zero line may be observed.

GALVANOMETERS.

The mirror galvanometer, as arranged by Professor Thomson, shows the deflections of the needle by the reflection of a ray of light upon an equally divided scale. As the angular deflections which produce the movements of the ray of light upon the scale are small, it is assumed that the values which are read off, and which are proportional to the tangents of twice the angles of deflection, are also proportional to the currents producing them.

The sine galvanometer is turnable about a pin in its centre. When the needle is deflected from the zero, the coils are turned after it until the zero point is brought again to coincide with the needle. The strength of current producing the deflection is then directly proportional to the sine of the angle through which the coils are turned.

The tangent galvanometer has its coil always placed in the plane of the magnetic meridian, and has a diameter at least ten times the length of the needle. When the needle is deflected, the current producing the deflection is directly proportional to the tangent of the angle.

In absolute measure the current strength, I, producing the deflection α°, is

$$I = 1{\cdot}764 \frac{r^2}{L} \tan \alpha^\circ ;$$

in which 1·764 units of force = the horizontal intensity of the earth's magnetism; r = the radius of the coil; and L its length, both being in metres.

When the coil of a tangent galvanometer contains n turns, its diameter being = d metres, the current causing a deflection, α°, will be

·1404d

$$I = 0{\cdot}5615 \frac{d}{n} \tan \alpha^\circ \text{ (absolute units of current).}$$

The ordinary galvanoscope may be used at times as a galvanometer, provided, in the two measurements which are to be compared, the same deflection is obtained either by the insertion of adjustable resistances, or by the arrangement of a shunt across the galvanoscope coils, by which the stronger current is reduced so that the required portion only passes through them.

Method of vibrations.—This may be employed with any galvanometer or galvanoscope having a single needle The coils are placed at right angles to the magnetic meridian and the number, m, of oscillations counted which the needle makes across the magnetic meridian when under the influence of the earth's magnetism alone. The circuit is then closed, by which a current, c, which is to be measured, is allowed to traverse the coils, and the number of oscillations, N, in the same period of time noted. With any other current, C, let the number of oscillations similarly observed be n; then as m^2 is proportional to the horizontal intensity of the earth's magnetism,

$$\frac{N^2 - m^2}{m^2} = \text{the force of the current, } c\text{, in terms of that}$$

of the horizontal intensity of the earth's magnetism; and $\frac{n^2 - m^2}{m^2}$ = the current, C, in the same unit.

The effect of a circular current upon a magnetic element (*Weber*).—When the distance of the magnetic element from the centre point of the current circle is x, its diameter y, the current g, and the magnetic intensity of the element which is deflected μ, the force J with which the deflection takes place is expressed by

$$J = \frac{2 \pi g \mu y^2}{(x^2 + y^2)^{\frac{3}{2}}}$$

To measure the resistance of a galvanometer when no second galvanometer is to be obtained.—Connect a single constant element, E, in the circuit of a known resistance, R ohms, and arrange a shunt, s, across the ends of the galvanometer coil so as to give a readable deflection. Then alter the resistance of the shunt from s to s' ohms, and the resistance R will have to be altered to R′ ohms in order to give the same deflection as before. With these data the resistance of the galvanometer is

$$= \frac{(R' - R)\, s s'}{R s' - R' s} \; . \; . \; . \; \text{(ohms)}.$$

Correction of throw of galvanometer for resistance of air.—The experimenter, after observing the throw, should keep his eye upon the scale and note the point which the needle or light spot reaches in its next return. The correction to be added for the air is $\frac{1}{4}$th of the difference between the two readings.

CONSTANTS OF GALVANOMETERS.

The figure of merit of a galvanometer is the resistance R_1 which in its circuit, with one Daniell's element, gives a deflection of 1 degree of arc.

Connect the galvanometer, as in the method given below. If d is in degree of arc,

$$R_1 = d \,.\, \frac{G+s}{s} \,.\, \left(\frac{G\,s}{G+s} + r + R\right) \quad . \quad . \quad . \quad \text{ohms.}$$

If d is given in divisions of the mirror scale, let the distance of the scale from the mirror be l (in the same measure as d), then

$$\frac{d}{l} = \tan 2\,a.$$

Having found a in this way

$$R_1 = a \frac{G+s}{s}\left(\frac{G\,s}{G+s} + R + r\right) \quad . \quad . \quad . \quad \text{ohms.}$$

Mirror galvanometers may be compared *with each other* by the resistance necessary to produce, with Daniell's element, a deflection of 1 division of the scale.

To find the deflection due to the current of one cell, with a resistance of one megohm.—Connect a shunt across the ends of the galvanometer coil, and put it in circuit with one cell, and R ohms. Let the resistance of the galvanometer be G ohms; that of the shunt s ohms; that of the cell r ohms, and the observed deflection d divisions. The *constant* deflection, D, with a resistance of one megohm, would be

$$D = d \,.\, \frac{G+s}{s} \,.\, \left(R + r + \frac{G\,s}{G+s}\right) 10^{-6} \,.\, \text{divisions.}$$

It is customary to make the resistance of the whole circuit, that is, the sum of the resistance (R), of the cell (r), and of the parallel $\left\{\begin{matrix}\text{galvanometer}\\ \text{and shunt}\end{matrix}\right\}$, equal to 10,000, in which case the *constant*

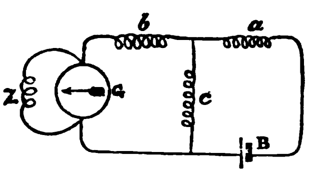
$$D = d \cdot \frac{G + s}{s} \cdot \frac{1}{100} \cdot \quad . \quad . \text{ divisions.}$$

If the shunt, s, have a multiplying power of 100, with $\left(R + r + \frac{G + s}{G s}\right) = 10{,}000$ ohms, the *constant*

$$D = d.$$

To find the resistance which, with a given battery, produces the unit deflection.

1. **Indirect method** (*Hockin*).—The three sets of resistance coils, a, b, and c, are arranged as in the figure,



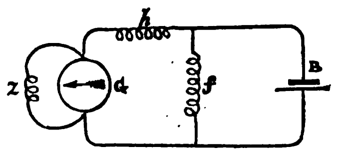
with the battery, B, a galvanometer, G, and a shunt, z, equal in resistance to $\frac{1}{999}$ of the galvanometer coils. The resistance c is made = 1000 ohms, and a and b adjusted until a convenient deflection, d, is obtained. Then they are altered, a to a_1, b to b_1, and c to c_1; the same deflection, d, being obtained as before.

Then

$$R_1 = 0{\cdot}001\, d \left\{ (a_1 - a) \frac{(b + c + 0{\cdot}001\ G)\,(b_1 + c_1 + 0{\cdot}001\ G)}{(b - b_1)\, c} - c \right\}$$

megohms.

2. **Direct method** (*Hockin*).—By this method the resistance of the battery, B, has to be calculated; h and f being variable resistances, and g the resistance of the shunted galvanometer. First, h is adjusted (whilst the



circuit f is broken) until a convenient deflection is obtained; then f is joined up as shown in the figure, and h adjusted to h_1 until the same deflection is obtained as before. With these data we obtain the battery resistance

$$B = f \frac{h - h_1}{g + h_1}$$

A direct deflection, d, is obtained with a resistance, K, in circuit. The resistance, R, is

$$R_1 = 0{\cdot}001\, d\,(K + B + g) \quad . \quad . \quad . \quad \text{(megohms)}.$$

3. **Simple shunt circuit.**—Let the galvanometer be connected up with the battery and a large resistance (about 10000 ohms); connect an adjustable shunt, s, across the galvanometer until a suitable deflection (whose

function is d) is obtained; then if the battery resistance is r ohms,

$$R_1 = \frac{d}{10^6}\left\{G + (R + r)\frac{G + s}{s}\right\} \quad . \quad . \quad . \quad \text{(megohms)},$$

G being the resistance of the galvanometer in ohms. The resistance, r, of the battery can generally be estimated sufficiently nearly to avoid practical error, and the resistance, R, be reduced by $\left(r + \frac{G s}{G + s}\right)$ ohms, so as to make the whole circuit resistance = 10000, then

$$R_1 = d\frac{G + s}{s}\frac{1}{100} \text{ (megohms)}.$$

And if $s = \frac{G}{99}\left(\text{or } \frac{G + s}{s} = 100\right)$, which will be found, in general work, to be a useful proportion,

$$R_1 = d \quad . \quad . \quad . \quad \text{(megohms)}.$$

To find the current (in B. A. units) which produces the unit deflection.

Connect the shunted galvanometer in circuit with a single element and a resistance coil.

$$\left.\begin{array}{rl} \text{Let } G = & \text{the galvanometer resistance} \\ s = & \text{the shunt resistance} \\ r = & \text{the resistance of the element} \\ R = & \text{the resistance coil} \end{array}\right\} \text{in ohms.}$$

E = the electro-motive force of the element in volts.

a = the function of the deflection obtained (division, sine, or tangent).

Then

$$C = \frac{E s}{a\left\{G(R + r + s) + s(R + r)\right\}} = \left\{\begin{array}{l}\text{the current which} \\ \text{produces the unit} \\ \text{of deflection.}\end{array}\right.$$

And the function of any other deflection of the galvanometer multiplied by this constant will express the strength of the current producing the deflection in B. A. units of current.

It is convenient, in taking this constant, to make the total resistance of the circuit equal to 10000 ohms, or

$$R + r + \frac{G s}{G + s} = 10000,$$

and to make the multiplying power of the shunt 100, or

$$\frac{G + s}{s} = 100,$$

in which case the constant (C) for reduction to B. A. units of current is

$$C = \frac{E}{a} 10^{-6}$$

Example.—With a Dubois sine galvanometer and a Daniell's element we obtain with a $\frac{1}{100}$th shunt a deflection of 26°; $R + r + \frac{G s}{G + s} =$ 10,000 ohms; and E = 0·9268 volts. Sine 26° = 0·438.

$$C = \frac{0·9268}{0·438} \times 10^{-6} = 2·116 \times 10^{-6}.$$

Therefore with this galvanometer the sine of any deflection multiplied by 0·000002116 gives the B. A. units of current circulating in its coil at the moment. Thus, when 100 Daniell's elements were connected up with the galvanometer and a knot-length of gutta-percha covered core, a deflection of 11° was observed. The current, I, was therefore

$$I = \sin 11° \times 2·116 \times 10^{-6} = 0·404 \times 10^{-6} \text{ (B. A. units).}$$

According to Ohm's law, $I = \frac{E}{R}$ or $R = \frac{E}{I}$, and as in this case $E = 100 \times ·9268 = 92·68$ volts,

$$R = \frac{92·68}{·404 \times 10^{-6}} = 229 \times 10^{6} \text{ ohms,}$$

or 229 megohms.

E. R

Galvanometer wires may be wound so as to render the instruments very sensitive, with a minimum quantity of wire, by following the law given by Thomson. The curve forming the transverse section of the coil is expressed by

$$x^2 = \left(\frac{y}{a}\right)^{\frac{2}{3}} - y^2$$

x being the abscissæ from the zero point passing through the magnet, y the ordinates, and a a constant.*

MEASUREMENT OF ELECTRO-MOTIVE FORCES.

1. **Wiedemann's method.**—Two batteries to be compared, whose electro-motive forces are E and E′ volts, and whose resistances are R and R′ ohms, are connected up in the same circuit with a tangent galvanometer whose resistance is r ohms, so that their currents go the same way, and give a united current, I_s.

$$I_s = \frac{E + E'}{R + R' + r}$$

Then they are connected up so that their currents go in opposite directions through the same circuit, in which case the difference of the currents being I_d,

$$I_d = \frac{E - E'}{R + R' + r}$$

Whence

$$E' = E \frac{I_s - I_d}{I_s + I_d} \; . \; . \; \text{(volts)}.$$

2. **Method of equal deflections.**—Let the electro-

* "Cours de physique," par A. Boutan. Paris, 1867, p. 117.

motive forces be E and E′. Join the batteries up successively in the circuit of the same galvanometer with the various *total* resistances, R and R′, so that in each case the same deflection is obtained.

Then
$$E' = E\frac{R'}{R}$$

3. **When the electro-motive forces differ greatly** a shunt is employed to diminish the galvanometer deflection of the more powerful battery. Let g be the galvanometer resistance, and s that of the shunt; then

$$E' = E\frac{R'\frac{g+s}{s}}{R}$$

4. **When shunts are used for both measurements,**

$$E' = E\frac{R'\frac{g+s}{s}}{R\frac{g+s'}{s'}}$$

5. **Wheatstone's method.**—First: the battery, E volts, in circuit with resistance, R ohms, gives a deflection $\alpha°$. By adding r ohms, the deflection is reduced to $\beta°$.

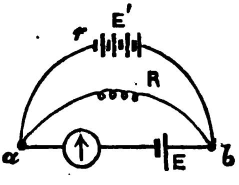
Secondly: the battery, E′ volts, in circuit with resistance, R′ ohms, is deflected $\alpha°$; which deflection is reduced to $\beta°$ by adding r' ohms.

$$E' = E\frac{r'}{r} \quad . \; . \; \text{(volts).}$$

6. **Poggendorff's method.**—The two points, *a* and *b*, form the common junction of three circuits;

1. The larger battery, E′ (volts),

2. An adjustable resistance, R,
3. A galvanometer and measuring cell, E (volts).



The currents of both batteries go in the same direction through R, which is adjusted until no current goes through the galvanometer. The resistance of the battery circuit E′, between *a* and *b*, being *r* ohms,

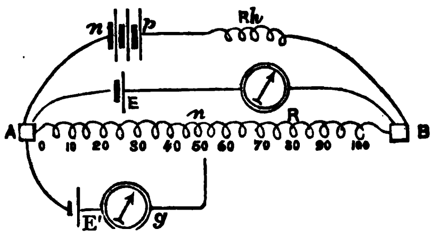
$$E' = E\,\frac{R + r}{R}\ \ldots\ \text{(volts).}$$

7. **When the resistance of the battery, E′, is not known,** insert a resistance, *r*, in the circuit of E′, and obtain a balance with R in the middle circuit. Then change *r* to *r′*, and R to R′, until a balance is re-established.

$$E' = E\,\frac{(r - r') + (R - R')}{(R - R')}\ \ldots\ \text{(volts).}$$

8. **Clark's method with the Potentiometer.**—R is a coil of platinum wire of 100 turns wound on an ebonite cylinder which revolves on its axis like a Wheatstone's Rheostat; the ends of the coil are connected to the axles which work in the blocks A and B; *p n* is a battery of several cells also connected to the blocks A and B, which sends a continuous current through R. By the rheostat, Rh., the total resistance of the circuit can be varied.

E is a standard element, connected to the blocks A and B, with an intervening galvanometer, which by a proper adjustment of the rheostat is just balanced by the battery *p n* in the manner before described, so that no current



passes. Thus far the arrangement is similar to that o Poggendorff. E′ is the cell whose tension or electromotive force we desire to measure, and this is connected with the block A and galvanometer *g*, and a travelling contact *n*, which can be applied to any part of the wire R.

Assuming the standard battery, E, to be exactly balanced by *p n*, and to have a tension of 100, and calling the tension at A = 0, we have between A and B every tension from 0 to 100, and by applying the wire *n* successively to different parts of the wire R, we soon find a point where the tension of E′ is balanced, no current passing through *g*. A scale of equal parts measured along R gives the tension of the cell E′ by simple inspection.

By the use of a mirror galvanometer, and by fixing a divided scale on the revolving cylinder, it is easy to measure tensions accurately to the ten thousandth or even hundred thousandth part of a Daniell's cell. When

the battery E′, which we wish to measure, is more powerful than the standard battery E, their positions are reversed, and E is connected to the galvanometer g and wire n.

Laws' Method.—The two elements, or batteries, to be compared, are used in succession to charge a given condenser. Their electro-motive forces are in direct proportion to the charges communicated by them to the condenser. When batteries of very different values are to be compared, a shunt must be used in reading the throw due to the charge current of the larger one.

Maximum Current.—The maximum current of a battery of given surface of plates is obtained when the resistance of the battery is equal to that of the circuit exterior to it.

If we have N elements, the resistance of each being r ohms, and the external resistance of the circuit R ohms, we must arrange the battery in n rows of each $\frac{N}{n}$ elements in series, and these rows we must then connect up parallel with each other.

The number of rows will be

$$n = \sqrt{\frac{N\,r}{R}}$$

The resistance of each row being

$$\frac{N}{n}\,r = n\,R \quad . \quad . \quad . \quad \text{ohms.}$$

TELEGRAPH BATTERIES.

Daniell's element consists of a pole of sheet copper in a saturated solution of sulphate of copper, and a pole of amalgamated zinc in dilute sulphuric acid; the two solutions being separated by a porous diaphragm. The electro-motive force of this element is equal to 1·079 volts.

Minotti's element, which is the simplest and least expensive form of Daniell's element, consists of an earthenware jar, at the bottom of which is placed a disc of sheet copper connected to an insulated wire. The jar is half filled with sulphate of copper crystals, over which a disc of felt is placed, and above this a thick layer of sawdust to act as a diaphragm. The zinc plate is circular, and lies upon the sawdust. When in use, the cell is filled up with acidulated water. A thin layer of oil above this is found useful to prevent evaporation.

Marié Davy's element consists of a carbon pole in a paste of proto-sulphate of mercury and water contained in a porous pot; and a zinc pole in dilute sulphuric acid. The electro-motive force of this element is 1·524 volts.

Leclanché's element consists of a zinc rod in a solution of ordinary commercial sal-ammoniac; the negative pole is a prism of carbon, tightly packed into a porous pot with a mixture of peroxide of manganese and carbon, in the form of coarse powder. Its electromotive force is about 1·48 volts.

Faure's Carbon Battery.—In this battery an outer jar contains a solution of common salt and a zinc

cylinder. Inside the zinc cylinder is the carbon pole, which is made in the form of a bottle, and is filled with concentrated nitric acid. This bottle is closed by a carbon stopper to prevent the escape of fumes, and performs the double function of porous pot and of carbon pole; the nitrous gas rises inside the bottle, and increases the pressure, forcing the acid through the porous cell in sufficient quantity to keep up the action.

Chromate of potassium element.—Prepare two solutions, the first to be made by dissolving 2 ounces of bichromate of potash in 20 ounces of hot water, and when cold add 10 ounces of strong sulphuric acid. As this addition will cause the solution to become warm, it must be allowed to cool before being used.

The second is a saturated solution of common salt, which is made by adding salt to the required quantity of water until it ceases to dissolve any more.

To charge the battery with these solutions, the bichromate solution must be poured into the porous jar containing the carbon until it reaches about half an inch from the top; then pour the salt solution into the outer vessel containing the zinc until it reaches the same level. A battery thus excited will remain in full action for hours if used continually, or for days if occasionally employed.

The electro-motive force of a chromate element in which amalgamated zinc and carbon poles are both immersed in a solution of chromate of potassium is = 1·015 (Daniell's), or = 1·095 volts.

The electro-motive force of Grove's element has been determined by Poggendorff, as follows:—

Zinc in Sulphuric Acid.	Platinum in Nitric Acid.	Electro-motive Force.	
		Daniell's = 1	Volts.
Sp. gr. = 1·136 . .	Concentrated . . .	1·812	1·955
Sp. gr. = 1·136 . .	Sp. gr. = 1·33 . .	1·678	1·809
Sp. gr. = 1·060 . .	Sp. gr. = 1·33 . .	1·603	1·730
Sp. gr. = 1·136 . .	Sp. gr. = 1·19 . .	1·558	1·681
Sp. gr. = 1·060 . .	Sp. gr. = 1·19 . .	1·512	1·631
Sulphate of Zinc solution	Sp. gr. = 1·33 . .	1·550	1·673
Solution of common Salt	Sp. gr. = 1·33 . .	1·765	1·905

The electro-motive force of elements whose negative poles are formed by amalgams of some of the metals contained in porous pots have been found by Wheatstone to be as follows:—

Amalgam of	Solution of	Positive Pole.	Daniell's = 1	Volts.
Potassium	Sulphate of Zinc . .	Zinc	0·967	1·043
Ditto	Sulphate of Copper .	Copper	1·967	1·122
Ditto	Chloride of Platinum .	Platinum	2·30	2·482
Ditto	Sulphuric Acid . .	Per-oxide of Lead . . .	3·267	3·525
Ditto	Ditto . .	Ditto of Manganese	2·80	2·921
Zinc	Sulphate of Copper . .	Copper	1·00	1·079
Ditto	Nitrate of Copper .	Ditto	0·967	1·043
Ditto	Chloride of Platinum .	Platinum	1·333	1·438
Ditto	Sulphuric Acid . .	Per-oxide of Lead . .	2·267	2·446
Ditto	Ditto . .	Ditto of Manganese	1·80	1·942

TABLE.—Electro-motive forces of some Galvanic Elements when subjected to heat.—(*Sabine.*)

No.	ELEMENT.	Temperature.	Electro-motive force.	Percentage difference.	REMARKS.
1	Daniell's .	18°C. 100° 22°	1·000 1·015 0·998	.. + 1·5% − 0·0	Taken as unit.
2	Marié Davy's	21°C. 100° 21° 22°	1·412 1·322 1·339 1·412	.. − 6·4% − 5·2 0·0	Daniell's = 1. After 3 hours. After 24 hours.
3	Chromate of potassium	18°C. 100° 20° 100° 18° 18° 18°	1·477 1·258 1·513 1·258 1·507 1·467 1·467	.. −14·8% + 2·5 − 14·8 + 2·1 − 0·7 − 0·7	Daniell's = 1. After 18 hours. After 42 hours.

The polarization of plates of metals in different fluids. Daniell = 1.

1. Platinum plates in diluted sulphuric acid (6 parts acid to 100 parts water) . . . . . 2·52
2. Platinum plates in nitric acid . . . . 1·14
3. Copper plates in sulphuric acid . . . . . . 1·00
4. Zinc plates in sulphuric acid . . . . 0·67
5. Graphite plates in nitric acid . . . . 0·58
6. Amalgamated zinc plates in sulphuric acid. . 0·42
7. Iron plates in sulphuric acid . . . . 0·15

TABLE of Electro-motive Forces of useful Elements.

No.	Name.	Negative Pole.	In	Positive Pole.	In	Electro-motive force.
						Volts.
1	Daniell (I.). (Unit).	Amalgamated Zinc.	1 Sulphuric acid and 4 Water.	Copper	Saturated solution sulphate copper in water.	1·079
2	Daniell (II.). (Telegraph).	Amalgamated Zinc.	1 Sulphuric acid and 12 Water.	Copper.	Saturated solution sulphate copper in water.	0·978
3	Daniell.	Amalgamated Zinc.	1 Sulphuric acid and 12 Water.	Copper.	Nitrate Copper and Water (Sat.).	1·000
4	Marié Davy.	Amalgamated Zinc.	1 Sulphuric acid and 12 Water.	Carbon.	Paste of proto sulphate of mercury and water.	1·524
5	Le Clanché.	Amalgamated Zinc.	Water containing Sal ammoniac.	Carbon surrounded by peroxide of magnesia and carbon particles.	Water and sal ammoniac.	1·481
6	Bunsen.	Amalgamated Zinc.	1 Sulphuric acid and 12 Water.	Carbon.	Nitric acid (fuming).	1·964
7	Bunsen.	Amalgamated Zinc.	1 Sulphuric acid and 12 Water.	Carbon.	Nitric acid (1·38)	1·888
8	Chromate.	Amalgamated Zinc.	100 Water, 12 Bichromate of potassium, 25 Sulphuric acid.	Carbon.	1 Sulphuric acid and 12 Water.	2·028
9	Grove.	Amalgamated Zinc.	1 Sulphuric acid and 4 Water.	Platinum.	Nitric acid (fuming).	1·956

Sulphuric Acid.

Table of the Specific Gravities of diluted English Sulphuric Acid (sp. gr. = 1·842) for use in Galvanic Elements.

Mixture parts by weight.		Specific Gravity at 17·5° C.	Mixture parts by weight.		Specific Gravity at 17·5° C.	Mixture parts by weight.		Specific Gravity at 17·5° C.
Sulphuric Acid	Water.		Sulphuric Acid.	Water.		Sulphuric Acid.	Water.	
0	100	1·000	17	83	1·115	34	66	1·245
1	99	1·006	18	82	1·122	35	65	1·253
2	98	1·012	19	81	1·129	36	64	1·261
3	97	1·018	20	80	1·136	37	63	1·269
4	96	1·025	21	79	1·143	38	62	1·277
5	95	1·032	22	78	1·150	39	61	1·285
6	94	1·038	23	77	1·157	40	60	1·293
7	93	1·045	24	76	1·165	41	59	1·301
8	92	1·052	25	75	1·173	42	58	1·309
9	91	1·059	26	74	1·181	43	57	1·317
10	90	1·066	27	73	1·189	44	56	1·326
11	89	1·073	28	72	1·197	45	55	1·335
12	88	1·080	29	71	1·205	46	54	1·344
13	87	1·087	30	70	1·213	47	53	1·353
14	86	1·094	31	69	1·221	48	52	1·362
15	85	1·101	32	68	1·229	49	51	1·371
16	84	1·108	33	67	1·237	50	50	1·380

COMMON SALT SOLUTION.

Specific Gravities of Various Strengths.

Salt in 100 parts of solution.	Specific Gravity at 17·5.	Salt in 100 parts of solution.	Specific Gravity at 17·5.	Salt in 100 parts of solution.	Specific Gravity at 17·5.
25·0	1·19200	21·9	1·16627	18·9	1·14181
24·9	1·19117	21·8	1·16544	18·8	1·14102
24·8	1·19034	21·7	1·16461	18·7	1·14023
24·7	1·18954	21·6	1·16378	18·6	1·13944
24·6	1·18868	21·5	1·16295	18·5	1·13865
24·5	1·18785	21·4	1·16212	18·4	1·13786
24·4	1·18702	21·3	1·16129	18·3	1·13707
24·3	1·18619	21·2	1·16046	18·2	1·13628
24·2	1·18536	21·1	1·15963	18·1	1·13549
24·1	1·18453	21·0	1·15880	18·0	1·13470
24·0	1·18370	20·9	1·15797	17·9	1·13391
23·9	1·18287	20·8	1·15714	17·8	1·13312
23·8	1·18204	20·7	1·15631	17·7	1·13233
23·7	1·18121	20·6	1·15548	17·6	1·13154
23·6	1·18038	20·5	1·15465	17·5	1·13075
23·5	1·17955	20·4	1·15382	17·4	1·12996
23·4	1·17872	20·3	1·15299	17·3	1·12917
23·3	1·17789	20·2	1·15216	17·2	1·12838
23·2	1·17706	20·1	1·15133	17·1	1·12759
23·1	1·17623	20·0	1·15050	17·0	1·12680
23·0	1·17540	19·9	1·14971	16·9	1·12607
22·9	1·17457	19·8	1·14892	16·8	1·12522
22·8	1·17374	19·7	1·14813	16·7	1·12443
22·7	1·17291	19·6	1·14734	16·6	1·12364
22·6	1·172·8	19·5	1·14655	16·5	1·12285
22·5	1·17125	19·4	1·14576	16·4	1·12206
22·4	1·17042	19·3	1·14497	16·3	1·12127
22·3	1·16959	19·2	1·14418	16·2	1·12048
22·2	1·16876	19·1	1·14439	16·1	1·11969
22·1	1·16793	19·0	1·14260	16·0	1·11890
22·0	1·16740				

NITRIC ACID.

Specific Gravities of Various Strengths.

Specific Gravity.	NO_5 in 100 parts.	Specific Gravity.	NO_5 in 100 parts.	Specific Gravity.	NO_5 in 100 parts.
1·500	79·70	1·383	53·40	1·196	27·10
1·498	78·90	1·378	52·60	1·190	26·30
1·496	78·11	1.373	51·81	1·183	25·50
1·494	77·31	1·368	51·07	1·177	24·71
1·491	76·51	1·363	50·21	1·171	23·91
1·488	75·72	1·358	49·41	1·165	23·11
1·485	74·92	1·353	48·62	1·159	22·32
1·482	74·12	1·348	47·82	1·153	21·52
1·479	73·32	1·343	47·02	1·147	20·72
1·476	72·53	1·338	46·23	1·140	19·93
1·473	71·73	1·332	45·43	1·135	19·13
1·470	70·93	1·327	44·63	1·129	18·33
1·467	70·14	1·322	43·84	1·123	17·53
1·464	69·34	1·316	43·04	1·117	16·74
1·460	68·54	1·311	42·24	1·111	15·94
1·457	67·75	1·306	41·44	1·105	15·14
1·453	66·95	1·300	40·65	1· 99	14·35
1·450	66·16	1·295	39·85	1·c94	13·55
1·446	65·35	1·289	39·05	1·088	12·75
1·442	64·56	1·283	38·26	1·082	11·96
1·439	63·76	1·277	37·46	1·076	11·16
1·435	62·96	1·271	36·66	1·071	10·36
1·431	62·17	1·264	35·87	1·065	9·56
1·427	61·37	1·258	35·07	1·060	8·77
1·423	60·57	1·252	34·27	1·054	7·97
1·419	59·78	1·246	33·47	1·049	7·17
1·415	58·98	1·240	32·68	1·043	6·38
1·411	58·18	1·234	31·88	1·038	5·58
1·407	57·38	1·228	31·08	1·032	4·78
1·402	56·59	1·221	30·29	1·027	3·99
1·398	55·79	1·215	29·49	1·021	3·19
1·385	54·99	1·208	28·69	1·016	2·39
1·388	54·20	1·202	27·90	1·011	1·59

Voltameter.

The volume of gas developed, per second, is directly proportional to the strength of the current.

Let v_h be the volume of gas developed.
t its temperature in deg. Centigrade.
h the barometric pressure in millimetres.

then the volume (v_0) at 0° Cent. is

$$v_0 = \frac{hv_h}{760\,(1 + 0{\cdot}003665\,t)}.$$

The B.A. unit of current develops 10·32 cubic centimetres of mixed gas per min. at a temperature of 0° C., and a pressure of 760^{mm} mercury.

Jacobi defined his *unit of current* to be *that current which, in one minute, at a temperature of* 0° *Cent., and under* 760 *millim. barometric pressure, develops one cubic centimetre of explosive gas.* It is therefore equal $\frac{1}{10{\cdot}32}$ vebers per second.

Electrolysis.—When part of the circuit of an electric current is composed of a fluid conductor, decomposition of its elements takes place, the constituents resolving themselves in the vicinity of the one or other pole according to their relative electro-positiveness.

In a circuit containing water through which an unit of current is circulating (one veber per second), a volume of mixed gases equivalent to 0·00142 grains of water will be generated per second.

Therefore, in a circuit in which the quantity of current circulating is equal to n vebers per second, the weight, W,

of water decomposed in t seconds will be W = 0·00142 $n\,t$ grains, of which the weight w of hydrogen gas will be

$$w = \frac{1}{9}.\ 0·00142\ n\,t = 0·000158\ n\,t \text{ grains.}$$

If instead of water we have a solution of some metal whose atomic weight is a, the weight w' of this metal deposited upon the negative electrode in t seconds, whilst a strength of current of n farads circulates will be $w' = 0·000158\ a\,n\,t$ grains.

Heat produced in a Conductor by a current.

θ = 0·2405 R $C^2\,t$ . . (units of heat).

R = Resistance of wire in ohms.

C = Current strength, in vebers, per second.

t = time in seconds.

θ = heat (in units of heat).

Example.—In a circuit in which is contained a battery of galvanic elements the current strength is equal to one B A unit (or about equivalent to that of a circuit containing one Daniell's element and 1 unit resistance). This current circulates through a coil of thin wire, which has 1·2 ohm's resistance, during 5 seconds. What amount of heat (θ) is thereby developed in the wire?

Answer.—θ = 0·2405 × 1·2 × 5 = 1·443 units of heat. That is to say that, had this wire coil been plunged into water during the time that the current was circulating in it, the heat developed would have been sufficient to raise 1·443 grammes of water 1° Cent. from its point of greatest density.

COPPER.

The specific gravity of copper wire, according to the best authorities, is about 8·899.

One cubic foot weighs about 550 lbs.

One cubic inch weighs 0·32 lbs.

The ordinary breaking weight of copper wire is about 17 tons per square inch, varying, however, greatly according to the size and degree of hardness.

The weight, per nautical mile, of any copper wire is about $\frac{d^2}{55}$ lbs., d being the diameter in mils.

The weight, per knot, of a copper strand is about $\frac{d^2}{70 \cdot 4}$ lbs.

The weight, per statute mile, of any copper wire is $\frac{d^2}{63}$ lbs. A mile of No. 16 wire weighs in practice from 63 to 66 lbs.

The diameter of any copper wire weighing w lbs. per nautical mile is $7 \cdot 4 \sqrt{w}$ mils.

The diameter of any copper wire weighing w lbs. per statute mile is $7 \cdot 94 \sqrt{w}$ . . mils.

The diameter of a copper strand weighing w lbs. per nautical mile is about $8 \cdot 4 \sqrt{w}$ . . . . mils.

The resistance of a nautical mile of pure copper weighing 1 lb. is—

at 32°	Fahr.	1091·22	ohms.
at 60°	"	1155·48	"
at 75°	"	1192·43	"

The resistance per nautical mile of any pure copper wire or strand weighing w lbs., is $\frac{1192 \cdot 45}{w}$ at 75° Fahr.

The resistance per nautical mile of any pure copper wire d mils in diameter, is $\frac{65306}{d^2}$ ohms at 75° Fahr.

The resistance per statute mile of any pure copper wire is $\frac{54892}{d^2}$ ohms at 60° Fahr.

The resistance per nautical mile of any pure copper strand is $\frac{83964}{d^2}$ ohms at 75° Fahr.

The resistance, per knot, of a cable conductor is equal to 120,000 divided by the product of the percentage conductivity of the copper and its weight, per knot, in lbs.

The resistance of a statute mile of pure copper weighing 1 lb. is 1002·4 ohms at 60° Fahr. No. 16 copper wire of good quality has a resistance of about 19 ohms.

The resistance of a statute mile of pure copper weighing w lbs., is $\frac{1002{\cdot}4}{w}$ ohms at 60° Fahr.

The resistance of any pure copper wire l inches in length, weighing n grains =

$$\frac{{\cdot}001516 \times l^2}{n} \text{ ohms.}$$

The conducting power of a pure metal wire, at 0° Cent., being C_0, its conducting power, at t° Cent. is

$$C_t = C_0\,(1 - {\cdot}003765\,t + {\cdot}00000834\,t^2)$$

The resistance of copper increases as the temperature rises 0·21 per cent. for each degree Fahr., or about 0·38 per cent. for each degree Centigrade. A table of resistances at different temperatures is given below.

TABLE for Calculating approximately the Resistance of Copper at different Temperatures Fahr.

To increase from lower temperature to higher, multiply the Resistance by the Number in Column 2.				To reduce from higher temperature to lower, multiply the Resistance by the Number in Column 4.			
No. of Degrees.	Column 2.	No. of Degrees.	Column 2.	No. of Degrees.	Column 4.	No. of Degrees.	Column 4.
0	1·	16	1·0341	0	1·	16	0·9670
1	1·0021	17	1·0363	1	0·9979	17	0·9650
2	1·0042	18	1·0385	2	0·9958	18	0·9629
3	1·0063	19	1·0407	3	0·9937	19	0·9609
4	1·0084	20	1·0428	4	0·9916	20	0·9589
5	1·0105	21	1·0450	5	0·9896	21	0·9569
6	1·0127	22	1·0472	6	0·9875	22	0·9549
7	1·0148	23	1·0494	7	0·9854	23	0·6529
8	1·0169	24	1·0516	8	0·9834	24	0·9509
9	1·0191	25	1·0538	9	0·9813	25	0·9489
10	1·0212	26	1·0561	10	0·9792	26	0·9469
11	1·0233	27	1·0583	11	0·9772	27	0·9449
12	1·0255	28	1·0605	12	0·9751	28	0·9429
13	1·0276	29	1·0627	13	0·9731	29	0·9409
14	1·0298	30	1.0650	14	0·9711	30	0·9390
15	1·0320			15	0·9690		

The conductivity of any copper wire is obtained by multiplying its calculated resistance by 100, and dividing the product by its actual resistance. Pure copper is taken as = 100.

The conductivity of any copper wire, l inches in length, weighing w grains, and having a resistance of r ohms, is

$$\frac{0{\cdot}1516\, l^2}{w\, r}.$$

The conductivity of any copper may be determined by taking a standard having a resistance equal to 100 inches pure copper, weighing 100 grains at 60° Fahr.

(= 0·1516 ohms). The conductivity of any other wire of similar resistance will be as the square of its length in inches, divided by its weight in grains.

To find the weight (w) of copper in lbs. per knot required for a given speed of working through a given length of cable. Let s be the speed determined upon, in words per minute; l the length in knots; and a the ratio which is intended to be employed between the weights of G. P. and copper strand.*

1. When the speed s is obtained with the reflecting galvanometer,

$$w = \frac{s\,l^2}{\log\left(1·05\sqrt{1 + 6·8\,a}\right) 600000} \text{ lbs. per knot.}$$

2. When the speed s is obtained with the Morse apparatus,

$$w = \frac{s\,l^2}{\log\left(1·05\sqrt{1 + 6·8a}\right) 36500} \text{ lbs. per knot.}$$

When the cable is to be insulated with Hooper's india-rubber, the data having been determined upon as before,

1. With the reflecting galvanometer,

$$w = \frac{s\,l^2}{\log\left(1·05\sqrt{1 + 5·7\,a}\right) 810{,}000} \text{ lbs. per knot.}$$

2. With Morse,

$$w = \frac{s\,l^2}{\log\left(0·95\sqrt{1 + 5·7\,a}\right) 49000} \text{ lbs. per knot.}$$

* In the Malta-Alexandria cable, $a \left(= \frac{400}{400}\right) = 1$; in the Atlantic cables, $a \left(= \frac{400}{300}\right) = 1·333$.

Example.—In a proposed cable it is determined to take equal weights of copper strand and gutta-percha (therefore $a = 1$); the length is 1792 knots; and it is required to work with the reflecting galvanometer at the maximum rate of 14 words a minute. The quantity of copper required will therefore be

$$\frac{14 \times 1792^2}{\log (1{\cdot}05 \sqrt{6{\cdot}8})\, 610000} = 168 \text{ lbs. per knot.}$$

Table for Calculating Resistance and Conducting Power of (pure) Copper.

(Temperatures in deg. Cent.)

Temp. Cent.	Resistance.	Conducting power.	Temp. Cent.	Resistance.	Conducting power.
0°	1·00000	1·00000	16°	1·06168	0·94190
1	1·00381	0·99624	17	1·06563	0·93841
2	1·00756	0·99250	18	1·06959	0·93494
3	1·01135	0·98878	19	1·07356	0·93148
4	1·01515	0·98508	20	1·07742	0·92814
5	1·01896	0·98139	21	1·08164	0·92452
6	1·02280	0·97771	22	1·08553	0·92121
7	1·02663	0·97406	23	1·08954	0·91782
8	1·03048	0·97042	24	1·09356	0·91445
9	1·03435	0·96679	25	1·09763	0·91110
10	1·03822	0·96319	26	1·10161	0·90776
11	1·04199	0·95970	27	1 10567	0·90443
12	1·04599	0·95603	28	1·10972	0·90113
13	1·04990	0·95247	29	1·11382	0·89784
14	1·05406	0·94893	30	1·11782	0·89457
15	1·05774	0·94541			

The percentage decrement in the conducting power of an impure metal, between 0° C. and 100° C., is to that of the pure one, between 0°C. and 100° C., as the conducting power of the impure metal at 100° C. is to that of the pure one at 100° C.—(*Matthiessen.*)*

* Phil. Trans., 1864, p. 167.

TABLE of RESISTANCES of PURE COPPER WIRES.—(*Hall.*)

Diameter in inches.	Diameter in millimetres.	Number of yards per lb.	Number of metres in 1 kilo.	Resistance in ohms of pure copper (unit of length 1760 yds. or 1609·31 mtrs).
·2302	5·847	2·095	4·223	1·00
·226	5·740	2·175	4·384	1·038
·198	5·029	2·834	5·713	1·352
·183	4·648	3·317	6·680	1·583
·175	4·445	3·628	7·314	1·731
·160	4·064	4·350	8·75	2·068
·136	3·454	6·007	12·11	2·867
·128	3·251	6·781	13·671	3·237
·107	2·717	9·705	19·555	4·623
·10	2·54	11·11	22·398	5·300
·092	2·336	13·125	26·46	6·266
·08	2·032	17·36	35·00	8·288
·07	1·778	22·67	45·71	10·82
·065	1·651	26·29	53·00	12·25
·0625	1·587	28·472	57·40	13·59
·06	1·521	30·864	62·223	14·73
·058	1·473	33·03	66·588	15·76
·056	1·422	35·432	71·431	16·91
·054	1·371	38·104	76·818	18·18
·052	1·32	41·091	82·839	19·61
·05	1·274	44·444	89·60	21·21
·048	1·219	48·225	97·222	23·02
·046	1·168	52·51	105·86	25·06
·044	1·117	57·39	115·70	27·39
·042	1·066	62·98	126·96	30·06
·04	1·016	69·444	140·00	33·14
·038	·965	77·16	155·50	36·72
·036	·914	85·766	172·91	40·92
·034	·864	95·29	292·70	45·48
·032	·813	108·5	218·74	51·79
·03	·762	123·46	248·90	58·93
·028	·711	141·72	285·71	67·65
·026	·660	164·36	331·35	78·46
·024	·609	192·9	380·26	92·08
·022	·558	229·56	462·80	109·58
·02	·508	277·78	560·01	132·59
·018	·457	342·94	691·36	163·69
·016	·406	434·03	875·00	207·17
·014	·355	569·51	1148·10	270·58
·012	·305	771·60	1555·50	368·30
·01	·254	1111·11	2239·80	530·35
·0095	·241	1231·10	2481·90	587·64
·009	·228	1371·7	2765·30	654·75
·0085	·216	1537·8	3100·20	734·05
·008	·203	1736·1	3500·00	828·67
·0075	·190	1975·3	3982·20	942·84
·007	·177	2267·6	4571·00	1082·4
·0065	·165	2629·9	5300·00	1225·3
·006	·152	3086·4	6222·30	1473·1
·0055	·139	3673·1	7404·90	1753·2
·005	·127	4444·4	8960·00	2121·4
·0045	·114	5487·0	11062·00	2619·0
·004	·106	6944·4	14000·00	3314·7
·0035	·088	9070·3	18285·00	4329·4
·003	·076	12346·0	24890·00	5892·7
·0025	·063	17777·0	35838·00	8485·6

RESISTANCE (R) in ohms of a knot-pound of COPPER WIRE of various CONDUCTIVITY at different TEMPERATURES.—(*Fuller.*)

Temp.	Percentage of Conductivity.									
	100·0%	98·0%	96·0%	94·0%	92·0%	90·0%	88·0%	86·0%	84·0%	82·0%
F.	R.	R.	R.	R.	R.	R.	R.	R.	R.	R.
32	1091	1113	1137	1161	1186	1212	1240	1269	1299	1331
33	1094	1116	1139	1163	1189	1215	1243	1272	1302	1334
34	1096	1118	1142	1166	1191	1218	1245	1274	1305	1337
35	1098	1121	1144	1168	1194	1220	1248	1277	1307	1339
36	1101	1123	1146	1171	1196	1223	1251	1280	1310	1342
37	1103	1125	1149	1173	1199	1226	1253	1283	1313	1345
38	1105	1128	1151	1176	1201	1228	1256	1285	1316	1348
39	1108	1130	1154	1178	1204	1231	1259	1288	1319	1351
40	1110	1133	1156	1181	1207	1233	1261	1291	1321	1354
41	1112	1135	1159	1183	1209	1236	1274	1293	1324	1357
42	1115	1137	1161	1186	1212	1239	1267	1296	1327	1359
43	1117	1140	1164	1188	1214	1241	1269	1299	1330	1362
44	1119	1142	1166	1191	1217	1244	1272	1302	1333	1365
45	1122	1145	1169	1193	1219	1246	1275	1304	1335	1368
46	1124	1147	1171	1196	1222	1249	1277	1307	1338	1371
47	1126	1149	1173	1198	1224	1252	1280	1310	1341	1374
48	1129	1152	1176	1201	1227	1254	1283	1313	1344	1377
49	1131	1154	1178	1203	1230	1257	1285	1315	1347	1380
50	1134	1157	1181	1206	1232	1260	1288	1318	1349	1382
51	1136	1159	1183	1208	1235	1262	1291	1321	1352	1385
52	1138	1161	1186	1211	1237	1265	1293	1324	1355	1388
53	1141	1164	1188	1213	1240	1267	1296	1326	1358	1391
54	1143	1166	1191	1216	1242	1270	1299	1329	1361	1394
55	1145	1169	1193	1218	1245	1273	1301	1332	1363	1397
56	1148	1171	1195	1221	1247	1275	1304	1334	1366	1400
57	1150	1173	1198	1223	1250	1278	1307	1337	1369	1402
58	1152	1176	1200	1226	1253	1280	1310	1340	1372	1405
59	1155	1178	1203	1228	1255	1283	1312	1343	1375	1408
60	1157	1181	1205	1231	1258	1286	1315	1345	1377	1411
61	1159	1183	1208	1233	1260	1288	1318	1348	1380	1414
62	1162	1185	1210	1236	1263	1291	1320	1351	1383	1417
63	1164	1188	1213	1238	1265	1293	1323	1354	1386	1420
64	1166	1190	1215	1241	1268	1296	1326	1356	1389	1423
65	1169	1193	1218	1243	1270	1299	1328	1359	1391	1425
66	1171	1195	1220	1245	1273	1301	1131	1362	1394	1428
67	1174	1197	1222	1248	1276	1304	1334	1365	1397	1431
68	1176	1200	1225	1251	1278	1307	1336	1367	1400	1434
69	1178	1202	1227	1253	1281	1309	1339	1370	1403	1437
70	1181	1205	1230	1256	1283	1312	1342	1373	1405	1440
71	1183	1207	1232	1258	1286	1314	1344	1376	1408	1443
72	1185	1209	1235	1261	1288	1316	1347	1378	1411	1445
73	1188	1212	1237	1263	1291	1320	1350	1381	1414	1448
74	1190	1214	1240	1266	1293	1322	1352	1384	1417	1451
75	1192	1217	1242	1268	1296	1325	1355	1386	1419	1454

To find the resistance, per knot, in ohms, of Copper in a Cable:—

Rule.—*Divide the value of R given in the above Table, by the weight of Copper, per knot.* The quotient is the resistance required.

Example.—The Copper of the Persian Gulf Cable weighs 225 lbs. per knot; its conducting power was 88°/₀ of pure Copper: what is its resistance, per knot, at 75° Fahr.?

In col. 88°/₀, opposite 75°, we find 1355.

The resistance is therefore $\frac{1355}{225} = 6{\cdot}02$ ohms per knot at the given temperature.

The resistance of any copper wire may be found for any temperature from its known resistance at any other temperature.

Refer to the column giving the percentage of conductivity in the Table. Divide the known resistance by the figure opposite the given temperature, and multiply by the figure in the same column, opposite the required temperature.

Example.—A conductor with 90% conductivity has a resistance of 130 ohms, at 60° F.; its resistance at 75° F. is therefore

$$\frac{130 \times 1325}{1286} = 133{\cdot}9 \text{ ohms.}$$

TABLE of No. of Yards per lb. of small Copper Wire.—(*Culley.*)

Birmingham Wire Gauge.	Diameter. Inches.	Diameter. Millimetres.	No. of yards in 1 pound.
24	·025	·635	177·7
25	·023	·584	210·0
26	·019	·483	307·8
27	·018	·457	342·94
28	·016	·406	434·03
29	·015	·381	493·8
30	·014	·355	569·51
31	·012	·305	771·6
32	·010	·254	1111·11
34	·0096	·244	1205·6
35	·0087	·221	1466·6
36	·0079	·200	1780·3
37	·0067	·170	2475·2
38	·0058	·147	3302·9
39	·0042	·106	6298·7
40	·0039	·099	7305·0
41	·0033	·084	10202·0

A strand of 7 No. 16 copper wires weighs 2·017 oz. per yard, 221·87 lb. per mile.

A strand of 7 No. 22 copper wires weighs ·944 oz. per yard, 103·81 lb. per mile.

Hooper's Tinned Copper Wire.

The coefficient corresponding to 1° Fahr. for Hooper's tinned copper wire is ·208 per cent. of its resistance at 75° Fahr.; consequently, to ascertain the resistance at any temperature, we have to add or subtract *t* times ·208 per cent. of the resistance at 75° Fahr., according as the temperature is above or below 75° Fahr. By the table,—multiply the resistance at 75° Fahr. by the coefficient corresponding to the number of degrees for temperatures above 75° Fahr., or divide by the same number for the number of degrees below 75° Fahr.

Diffs. of Temp. F.	Coefficient.	Diffs. of Temp. F.	Coefficient.	Diffs. of Temp. F	Coefficient.
1°	1·00208	16°	1·03328	31°	1·06448
2	1·00416	17	1·03536	32	1·06656
3	1·00624	18	1·03744	33	1·06864
4	1·00832	19	1·03952	34	1·07072
5	1·01040	20	1·04160	35	1·07280
6	1·01248	21	1·04368	36	1·07488
7	1·01456	22	1·04576	37	1·07696
8	1·01664	23	1·04784	38	1·07904
9	1·01872	24	1·04992	39	1·08112
10	1·02080	25	1·05200	40	1·08320
11	1·02288	26	1·05408	41	1·08528
12	1·02496	27	1·05616	42	1·08736
13	1·02704	28	1·05824	43	1·08944
14	1·02912	29	1·06032	44	1·09152
15	1·03120	30	1·06240	45	1·09360

The conducting power *of the following coppers have been determined by Matthiessen (chemically pure copper* = 100).

1.	Lake Superior, native, not fused	98·8 at 15·5
2.	„ „ fused, as it comes in commerce	92·6 at 15·0
3.	Burra Burra	88·7 at 14·0
4.	Best selected	81·3 at 14·2
5.	Bright copper wire	72·2 at 15·7
6.	Tough copper	71·0 at 17·3
7.	Demidoff	59·3 at 12·7
8.	Rio Tinto	14·2 at 14·8

Conducting power and resistance of copper.—The conducting power of pure copper is taken as 100. The copper used in telegraphy usually has a conducting power of 85 to 95 per cent. of that of pure copper.

A wire of pure copper 1 *inch long, and weighing* 1 *grain, has a resistance of* ·001516 *ohms, at* 60° F.

The resistance of any other wire of pure copper will be, at 60° F.

$$= \frac{\cdot 001516 \text{ ohms} \times \text{square of length in inches}}{\text{weight in grains}}.$$

GUTTA-PERCHA.

The specific gravity of gutta-percha is between 0·9693 and 0·981.

One cubic foot weighs between 60·56 and 61·32 lbs.

One nautical mile by 1 circular inch weighs about 2036 lbs.

Unstretched gutta-percha begins to elongate permanently at a strain of 6 cwt. per square inch.

The following are a few of the sizes and weights of solid gutta-percha cylindrical band:—

No.	Diameter in Mils.	Weight of Percha per Statute Mile.
		lbs.
—	143	36
8	161	46
7	171	52
6	194	66
5	214	81
4	221	86
3	247	108
2	276	134
1	289	147
0	340	204

The weight of gutta-percha per knot is 1 lb. for each 491 circular mils of sectional area; or for a solid cylinder, $\frac{d^2}{491}$ lbs.

The weight of gutta-percha per knot in any core is $\frac{D^2 - d^2}{491}$ lbs. where d is the diameter of the copper and D the diameter of the gutta-percha, both in mils.

The weight of gutta-percha per statute mile

$$= \frac{D^2 - d^2}{554 \cdot 5}.$$

The exterior diameter of any gutta-percha core $= \sqrt{70 \cdot 4\, w + 491\, W}$ mils, where w is the weight, in

lbs., per nautical mile of copper strand, and W that of gutta-percha. With a solid conductor the diam. =

$$\sqrt{55\,w + 491\,W} \quad . \quad . \quad \text{mils.}$$

The electro-static capacity per nautical mile of any gutta-percha core is approximately

$$\frac{0{\cdot}1877}{\text{Log } D - \log d} \quad . \quad . \quad \text{microfarads.}$$

The electro-static capacity of gutta-percha core as compared with india-rubber core of similar size is as 120 to 100 nearly.

The resistance per knot of a gutta-percha core of the best quality = 769 (Log D – log d) megohms at 75° Fahr.

The resistance of gutta-percha under pressure increases in the following ratio :—

Let R be the resistance at atmospheric pressure, the resistance under the pressure p lbs. per square inch =

$$R\,(1 + 0{\cdot}00023\,p).$$

The resistance of gutta-percha diminishes as the temperature increases ; the rate of decrease is as follows :—

Let R = resistance at the higher temperature ;
r = resistance at the lower temperature ;
t = the difference of temperature in degrees Fahr.,—then

$$\log \text{ of } R = \log r - t \log 0{\cdot}9399,$$

$$\text{and } \log \text{ of } r = \log R + t \log 0{\cdot}9399.$$

Tables of resistance of gutta-percha at different temperatures are given on the following pages.

Table of the relative resistance (after 1 minute) **of Gutta-percha** at different temperatures, by Bright and Clark's experiments with Persian Gulf core (1863).

Fahr.	Resistance.	Fahr.	Resistance.	Fahr.	Resistance.	Fahr.	Resistance.
32°	14·38	47°	5·675	62°	2·239	77°	·883
33	13·52	48	5·334	63	2·104	78	·830
34	12·71	49	5·013	64	1·978	79	·780
35	11·94	50	4·712	65	1·859	80	·733
36	11·22	51	4·429	66	1·747	81	·689
37	10·55	52	4·162	67	1·642	82	·648
38	9·917	53	3·912	68	1·543	83	·609
39	9·132	54	3·680	69	1·451	84	·572
40	8·760	55	3·456	70	1·364	85	·538
41	8·233	56	3·248	71	1·282	86	·506
42	7·738	57	3·053	72	1·204	87	·475
43	7·273	58	2·869	73	1·132	88	·447
44	6·835	59	2·697	74	1·064	89	·420
45	6·425	60	2·535	**75**	**1·00**	90	·394
46	6·038	61	2·382	76	·940		

The ratio of resistance for each degree Fahr. is given in the above table, taking that as the standard temperature of 75° Fahr. at 1. To reduce any resistance from any temperature to 75°, multiply it by the corresponding number in the table. For reduction to other temperatures, the case must be treated as one of simple proportion.

Mr. Willoughby Smith considers that for cables upon which the gutta-percha exceeds 0·11 inch in thickness, the above values are those still found experimentally. For cables whose thickness of gutta-percha, however, does not exceed 0·11 inch, Mr. Smith has found the following table to be more correct :—

Table of the relative resistance (after 1 minute) **of Ordinary Gutta-percha** at different temperatures, for all cores in which the thickness of G. P. does not exceed 0·11 inch.—(*W. Smith.*)

Temperature. Fahr.	Temperature. Cent.	Resistance.	Log Resistance.	Temperature. Fahr.	Temperature. Cent.	Resistance.	Log Resistance.
32	0·0	23·622	·373317	67	19·4	1·801	·255514
33	0·5	21·947	·341375	68	20·0	1·673	·223496
34	1·1	20·391	·309439	69	20·5	1·555	·191730
35	1·6	18·945	·277495	70	21·1	1·444	·159567
36	2·2	17·602	·245562	71	21·6	1·342	·127753
37	2·7	16·354	·213624	72	22·2	1·247	·095867
38	3·3	15·195	·181701	73	22·7	1·158	·063709
39	3·8	14·117	·149742	74	23·3	1·076	·031812
40	4·4	13·116	·117801	**75**	23·8	**1·000**	·000000
41	5·0	12·186	·085861	76	24·4	·9418	·973959
42	5·5	11·322	·053923	77	25·0	·8870	·947924
43	6·1	10·52	·022016	78	25·5	·8354	·921895
44	6·6	9·774	·990072	79	26·1	·7867	·895809
45	7·2	9·081	·958134	80	26·6	·7410	·869818
46	7·7	8·437	·926188	81	27·2	·6978	·843731
47	8·3	7·839	·894261	82	27·7	·6572	·817698
48	8·8	7·283	·862310	83	28·3	·6190	·791691
49	9·4	6·767	·830396	84	28·8	·5829	·765594
50	10·0	6·287	·798444	85	29·4	·5490	·739572
51	10·5	5·841	·766487	86	30·0	·5171	·713575
52	11·1	5·427	·734560	87	30·5	·4870	·687529
53	11·6	5·042	·702603	88	31·1	·4586	·661434
54	12·2	4·685	·670710	89	31·6	·4319	·635383
55	12·7	4·353	·638789	90	32·2	·4068	·609381
56	13·3	4·044	·606811	91	32·7	·3831	·583312
57	13·8	3·757	·574841	92	33·3	·3608	·557267
58	14·4	3·491	·542950	93	33·8	·3398	·531223
59	15·0	3·244	·511081	94	34·4	·3200	·505150
60	15·5	3·013	·478999	95	35·0	·3014	·479143
61	16·1	2·800	·447158	96	35·5	·2839	·453165
62	16·6	2·601	·415140	97	36·1	·2674	·427161
63	17·2	2·417	·383277	98	36·6	·2518	·401056
64	17·7	2·245	·351216	99	37·2	·2371	·374932
65	18·3	2·086	·319314	100	37·7	·2233	·348889
66	18·8	1·938	·287354				

Table for reducing Resistance of Gutta-percha to 24° Cent. or 75° Fahr. From Experiments with French Atlantic Cable core (1869).—(*Hockin.*)

Col. 3 gives Logarithm of Ratio of Resistance at Temperatures in Cols. 1 and 2 to Resistance at 24° Cent., &c.

Resistance after current has been kept on for one minute.

LOGARITHMS.					NATURAL NUMBERS.					
Temp.		Log $\frac{R_t}{R_{24}}$	Log $\frac{R_{24}}{R_t}$	Diff. for One Deg.	Temp.		$\frac{R_t}{R_{24}}$	Diff. for One Deg.	$\frac{R_{24}}{R_t}$	Diff. for One Deg.
Cent.	Fahr.				Cent.	Fahr.				
1	2	3	4	5	6	7	8	9	10	11
24	75·2	0·0000	0·0000	·0519	24	75·2	1·000	0·127	1·000	0·1126
23	73·4	0·0519	$\bar{1}$·9481	·0521	23	73·4	1·127	0·144	0·8874	0·1004
22	71·6	0·1040	$\bar{1}$·8960	·0524	22	71·6	1·271	0·162	0·7870	0·0894
21	69·8	0·1564	$\bar{1}$·8436	·0526	21	69·8	1·433	0·185	0·6976	0·0795
20	68·0	0·2090	$\bar{1}$·7910	·0528	20	68·0	1·618	0·209	0·6181	0·0709
19	66·2	0·2618	$\bar{1}$·7382	·0531	19	66·2	1·827	0·238	0·5472	0·0629
18	64·4	0·3149	$\bar{1}$·6851	·0533	18	64·4	2·065	0·270	0·4843	0·0560
17	62·6	0·3682	$\bar{1}$·6318	·0535	17	62·6	2·335	0·306	0·4283	0·0496
16	60·8	0·4217	$\bar{1}$·5783	·0538	16	60·8	2·641	0·348	0·3787	0·0441
15	59·0	0·4755	$\bar{1}$·5245	·0540	15	59·0	2·989	0·396	0·3346	0·0392
14	57·2	0·5295	$\bar{1}$·4705	·0543	14	57·2	3·385	0·450	0·2954	0·0349
13	55·4	0·5838	$\bar{1}$·4162	·0545	13	55·4	3·835	0·513	0·2607	0·0307
12	53·6	0·6383	$\bar{1}$·3618	·0547	12	53·6	4·348	0·583	0·2300	0·0272
11	51·8	0·6930	$\bar{1}$·3070	·0550	11	51·8	4·931	0·666	0·2028	0·0241
10	50·0	0·7479	$\bar{1}$·2521	·0552	10	50·0	5·597	0·758	0·1787	0·0214
9	48·2	0·8131	$\bar{1}$·1969	·0554	9	48·2	6·355	0·865	0·1573	0·0188
8	46·2	0·8585	$\bar{1}$·1415	·0557	8	46·2	7·220	0·987	0·1385	0·0167
7	44·6	0·9142	$\bar{1}$·0858	·0559	7	44·6	8·207	1·127	0·1218	0·0144
6	42·8	0·9701	$\bar{1}$·0299	·0561	6	42·8	9·334	1·286	0·1071	0·0130
5	41·0	1·0262	$\bar{2}$·9738	·0564	5	41·0	10·62	1·47	0·0942	0·0115
4	39·2	1·0826	$\bar{2}$·9175	·0566	4	39·2	12·09	1·69	0·0827	0·0101
3	37·4	1·1396	$\bar{2}$·8609	·0568	3	37·4	13·78	1·92	0·0726	0·0089
2	35·6	1·1960	$\bar{2}$·8040	·0571	2	35·6	15·70	2·21	0·0637	0·0076
1	33·8	1·1530	$\bar{2}$·7470	·0573	1	33·8	17·91	2·52	0·0558	0·0069
0	32·0	1·3103	$\bar{2}$·6897	·0575	0	32·0	20·43	2·90	0·0489	0·0061
−1	30·2	1·3679	$\bar{2}$·6321	·0578	−1	30·2	23·33	3·32	0·0429	0·0053
−2	28·4	1·4257	$\bar{2}$·5744	·0580	−2	28·4	26·65	3·81	0·0375	0·0047
−3	26·6	1·4837	$\bar{2}$·5163	·0582	−3	26·6	30·46	4·37	0·0328	0·0041
−4	24·8	1·5419	$\bar{2}$·4581	·0585	−4	24·8	34·83	5·01	0·0287	0·0036
−5	23·0	1·6004	$\bar{2}$·3996	·0587	−5	23·0	39·84	5·77	0·0251	0·0032
−6	21·2	1·6591	$\bar{2}$·3409		−6	21·2	45·61		0·0219	

$$\text{Formula.—Log}\,\frac{R_t}{R_{24}} = (0{\cdot}054598 - 0{\cdot}0001175\,t)\,(24 - t)$$

Table for reducing Resistance of Gutta-percha to 24° Cent. or 75° Fahr. From Experiments with French Atlantic Cable core (1869).—(*Hockin.*)

Col. 3 gives Logarithm of Ratio of Resistance at Temperatures in Cols. 1 and 2 to Resistance at 24° Cent., &c.

Resistance after Current has been kept on for an indefinite period.

LOGARITHMS.					NATURAL NUMBERS.					
Temp. Cent.	Temp. Fahr.	Log $\frac{R_t}{R_{24}}$	Log $\frac{R_{24}}{R_t}$	Diff. for One Deg.	Temp. Cent.	Temp. Fahr.	$\frac{R_t}{R_{24}}$	Diff. for One Deg.	$\frac{R_{24}}{R_t}$	Diff. for One Deg.
1	2	3	4	5	6	7	8	9	10	11
24	75·2				24	75·2	1·000		1·000	
23	73·4	0·0550	$\bar{1}$·9450	·0550	23	73·4	1·135	0·135	0·8810	0·1190
22	71·6	0·1112	$\bar{1}$·8888	·0562	22	71·6	1·292	0·157	0·7741	0·1069
21	69·8	0·1685	$\bar{1}$·8315	·0573	21	69·8	1·474	0·182	0·6785	0·0956
20	68·0	0·2287	$\bar{1}$·7731	·0584	20	68·0	1·686	0·212	0·5931	0·0854
19	66·2	0·2864	$\bar{1}$·7136	·0595	19	66·2	1·934	0·248	0·5172	0·0759
18	64·4	0·3470	$\bar{1}$·6530	·0606	18	64·4	2·223	0·289	0·4498	0·0674
17	62·6	0·4088	$\bar{1}$·5912	·0617	17	62·6	2·563	0·340	0·3902	0·0596
16	60·8	0·4716	$\bar{1}$·5284	·0629	16	60·8	2·962	0·399	0·3376	0·0526
15	59·0	0·5356	$\bar{1}$·4644	·0640	15	59·0	3·432	0·470	0·2914	0·0462
14	57·2	0·6007	$\bar{1}$·3993	·0651	14	57·2	3·987	0·555	0·2508	0·0406
13	55·4	0·6669	$\bar{1}$·3331	·0662	13	55·4	4·644	0·657	0·2152	0·0356
12	53·6	0·7342	$\bar{1}$·2658	·0673	12	53·6	5·423	0·779	0·1844	0·0308
11	51·8	0·7027	$\bar{1}$·1973	·0684	11	51·8	6·348	0·925	0·1575	0·0269
10	50·0	0·8722	$\bar{1}$·1277	·0696	10	50·0	7·451	1·103	0·1342	0·0233
9	48·2	0·9429	$\bar{1}$·0571	·0707	9	48·2	8·768	1·317	0·1140	0·0202
8	46·2	1·0147	$\bar{2}$·9853	·0718	8	46·2	10·34	1·56	0·0967	0·0173
7	44·6	1·0876	$\bar{2}$·9124	·0729	7	44·6	12·24	1·80	0·0817	0·0149
6	42·8	1·1616	$\bar{2}$·8384	·0740	6	42·8	14·71	2·47	0·0689	0·0128
5	41·0	1·2368	$\bar{2}$·7632	·0751	5	41·0	17·25	2·54	0·0580	0·0110
4	39·2	1·3130	$\bar{2}$·6870	·0763	4	39·2	20·56	3·31	0·0486	0·0093
3	37·4	1·3904	$\bar{2}$·6096	·0774	3	37·4	24·57	4·01	0·0407	0·0079
2	35·6	1·4689	$\bar{2}$·5311	·0785	2	35·6	29·44	4·87	0·0340	0·0067
1	33·8	1·5485	$\bar{2}$·4815	·0796	1	33·8	35·36	5·92	0·0283	0·0057
0	32·0	1·6292	$\bar{2}$·3708	·0807	0	32·0	42·57	7·21	0·0235	0·0048
−1	30·2	1·7011	$\bar{2}$·2889	·0818	−1	30·2	51·41	8·84	0·0195	0·0040
−2	28·4	1·7940	$\bar{2}$·2060	·0830	−2	28·4	62·24	10·83	0·0161	0·0034
−3	26·6	1·8781	$\bar{2}$·1219	·0841	−3	26·6	75·52	13·28	0·0130	0·0028
−4	24·8	1·6933	$\bar{2}$·0367	·0852	−4	24·8	91·89	16·37	0·0109	0·0024
−5	23·0	2·0496	$\bar{3}$·9504	·0863	−5	23·0	112·1	20·2	0·0089	0·0020
−6	21·2	2·1370	$\bar{3}$·8630	·0874	−6	21·2	137·1	25·0	0·0079	0·0010

$$\text{Formula.—Log}\ \frac{R_t}{R_{24}} = (0{\cdot}06788 - 0{\cdot}0005588\,t)\ (24 - t).$$

This table is calculated from experiments made on a

knot of core such as was used for the French Atlantic Cable—400 lbs. gutta-percha and 400 lbs. copper.

Three observations were made at temperatures 0·0 C., 11·7 C., and 24 C.

Loss of Charge.

TABLE showing the measured Rate of Fall of Tension in a Gutta-percha Cable (at a Temperature of 11·7° C.), when charged for many hours, and then insulated. From Experiments with French Atlantic Cable core.

Time.	Potential.	Time.	Potential.	Time.	Potential.
Minutes.		Minutes.		Minutes.	
0	100·0	21	50·8	42	33·0
1	95·8	22	49·5	43	32·5
2	91·9	23	48·3	44	31·9
3	88·3	24	46·9	45	31·3
4	85·0	25	45·0	46	30·9
5	81·9	26	45·0	47	30·5
6	79·0	27	44·0	48	29·9
7	76·4	28	43·2	49	29·6
8	73·6	29	42·2	50	29·1
9	71·3	30	41·3	51	28·7
10	69·2	31	40·5	52	28·3
11	67·1	32	39·6	53	27·9
12	64·8	33	39·0	54	27·4
13	62·8	34	38·2	55	27·1
14	61·2	35	37·4	56	26·6
15	59·5	36	36·8	57.	26·0
16	57·8	37	36·0	58	25·9
17	56·4	38	35·4	59	25·7
18	54·8	39	34·7	60	25·4
19	53·4	40	34·1		
20	52·0	41	33·7		

TABLE of ratio of $\frac{\text{charge}}{\text{discharge}}\left(=\frac{C}{c}\right)$ and of loss per cent. of charge by ordinary gutta-percha core, at temperatures between 32° and 90° Fahr. (After 1 minute's insulation.)

Temp. Fahr.	$\frac{C}{c}$	Loss %	Temp. Fahr.	$\frac{C}{c}$	Loss %	Temp. Fahr.	$\frac{C}{c}$	Loss %	Temp. Fahr.	$\frac{C}{c}$	Loss %
32°	1·029	2·8	47°	1·076	7·1	62°	1·204	16·8	77°	1·601	37·5
33	1·031	3·0	48	1·081	7·5	63	1·218	17·9	78	1·650	39·4
34	1·033	3·2	49	1·086	7·8	64	1·234	18·9	79	1·704	41·1
35	1·035	3·4	50	1·092	8·4	65	1·251	20·1	80	1·763	43·1
36	1·038	3·7	51	1·099	9·0	66	1·269	21·2	81	1·828	45·0
37	1·040	3·8	52	1·105	9·5	67	1·288	22·4	82	1·899	47·0
38	1·043	4·1	53	1·112	10·0	68	1·309	23·6	83	1·979	49·0
39	1·047	4·5	54	1·120	10·7	69	1·332	24·9	84	2·068	51·4
40	1·049	4·7	55	1·128	11·4	70	1·356	26·2	85	2·165	53·7
41	1·052	4·9	56	1·137	12·0	71	1·383	27·7	86	2·273	55·9
42	1·055	5·2	57	1·146	12·7	72	1·412	29·1	87	2·398	58·1
43	1·059	5·6	58	1·156	13·5	73	1·443	30·7	88	2·533	60·4
44	1·063	5·9	59	1·169	14·3	74	1·478	32·4	89	2·690	62·8
45	1·067	6·3	60	1·178	15·1	75	1·515	34·0	90	2·871	65·1
46	1·071	6·6	61	1·191	16·0	76	1·556	35·7			

The resistance of a cube FOOT of gutta-percha,

$= 12{\cdot}8 \times 10^6$ megohms at 75° F.

Its electro-static capacity $= 11{\cdot}3 \times 10^{-6}$ microfarads.

The resistance of a cube KNOT of gutta-percha,

$= 2100$ megohms at 75° F.

Its electro-static capacity = ·0687 microfarads.

A PLATE of gutta-percha, 1 square foot surface and 1 *mil* thick has a

Resistance = 1066 megohms at 75° F., and its *electro-static capacity* = ·1356 microfarads.

The insulation resistance in megohms at 75° F. of any ordinary gutta-percha cable or condenser multiplied by its electro-static capacity in microfarads = 144·4.

Table to find Resistance, after 1 minute, and Capacity per Knot, of any ordinary Gutta-percha core, from the relative Weights or Diameters of $\left(\frac{\text{Insulator}}{\text{Conductor}}\right)$.

$\frac{W}{w}$	$\frac{D}{d}$	Resistance per knot at 24° C. in megohms.	Electro-static capacity per knot in micro-farads.	$\frac{W}{w}$	$\frac{D}{d}$	Resistance per knot at 24° C. in megohms.	Electro-static capacity per knot in micro-farads.
1·00	2·80	360	·4007	1·26	3·10	395	·3657
1·01	2·81	361	·3995	1·27	3·11	396	·3647
1·02	2·82	363	·3982	1·28	3·12	397	·3638
1·03	2·83	364	·3969	1·29	3·13	398	·3628
1·04	2·85	366	·3945	1·30	3·14	399	·3619
1·05	2·86	367	·3934	1·31	3·15	400	·3611
1·06	2·87	368	·3921	1·32	3·17	402	·3593
1·07	2·88	369	·3910	1·33	3·18	403	·3583
1·08	2·90	372	·3886	1·34	3·19	404	·3579
1·09	2·91	374	·3864	1·35	3·20	405	·3569
1·10	2·92	375	·3853	1·36	3·21	406	·3559
1·11	2·93	376	·3841	1·37	3·22	407	·3544
1·12	2·94	377	·3830	1·38	3·23	408	·3538
1·13	2·95	378	·3820	1·39	3·24	409	·3531
1·14	2·96	379	·3808	1·40	3·25	410	·3521
1·15	2·98	381	·3788	1·41	3·26	411	·3512
1·16	2·99	382	·3777	1·42	3·27	412	·3502
1·17	3·00	383	·3766	1·43	3·28	413	·3493
1·18	3·01	384	·3756	1·44	3·29	414	·3484
1·19	3·02	386	·3746	1·45	3·30	415	·3476
1·20	3·03	387	·3735	1·46	3·31	416	·3467
1·21	3·04	388	·3725	1·47	3·32	418	·3459
1·22	3·06	390	·3705	1·48	3·33	419	·3450
1·23	3·07	391	·3695	1·49	3·34	420	·3441
1·24	3·08	392	·3686	1·50	3·35	421	·3433
1·25	3·09	393	·3675	1·51	3·36	422	·3425

When the ratio between the weights (W) of percha and of copper (w) are given, the resistance and capacity of the core are the same, whatever be the absolute value of these weights. The same is true of the relative diameters D and d. In using the above table we have only to ascertain the quotient $\frac{\text{weight of percha}}{\text{weight of copper}}$ or the $\frac{\text{diameter of percha}}{\text{diameter of copper}}$ and the table gives by inspection the resistance at 24° Cent. in megohms, and the electro-static capacity in microfarads.

Table giving some of the Dimensions and Relative Electrical Values of Gutta-Percha Cores as used in Different Cables.

No.	DESCRIPTION OF CORES. —		1	2	3	4	5	6	7	8	9
1	Weight of Copper per knot	lbs.	400	300	180	180	150	120	107	107	80
2	Weight of G. P. per knot	lbs.	4 0	400	240	212	200	175	224	150	120
3	Diameter of each wire of strand	ins.	·0555	·0481	·0372	·0372	·0340	·0304	·0287	·0287	·0248
4	Nearest B. W. G.		17	18	20	20	20	21	22	22	23
5	Diameter of strand	ins.	·1665	·1442	·1117	·1117	·1020	·0912	·0861	·0861	·0745
6	Diameter of Gutta-percha	ins.	·467	·461	·357	·337	·326	·304	·340	·282	·252
7	Thickness of G. P. coating	ins.	·150	·158	·122	·112	·102	·106	·127	·098	·089
8	Resistance per knot of G. P. in megohms at 75° Fahr. (taking French Atlantic core at 250 megs. per knot)		250	283	283	267	283	294	336	289	297
9	Resistance of Copper (supposed pure) in ohms, at 75° Fahr.		2·98	3·97	6·63	6·63	7·95	9·93	11·14	11·14	14·90
10	Ditto ditto with assumed conducting power 90%		3·28	4·37	7·29	7·29	8·74	10·92	12·25	12·25	16·39
11	$\log_\epsilon \frac{D}{d}$ (allowing 5% for strand)		1·081	1·122	1·157	1·155	1·210	1·252	1·421	1·235	1·237
12	Inductive capacity (calculated) taking French Atlantic Cable at ·420 microfarads		·420	·372	·353	·392	·372	·359	·315	·365	·336
	SPEED OF WORKING.										
13	Relative speed (taking speed through 2500 knots of French Atlantic Cable as 10·0 words per minute)	Knots 1000	62	52	32	30	26	22	22·5	19·4	15
		" 1500	28	23·6	14·2	13·3	11·8	9·8	10·0	8·6	6·6
		" 2000	15·6	13·3	8·0	7·5	6·6	5·5	5·6	4·8	3·7
		" 2500	10·0	8·5	5·1	4·8	4·2	3·5	3·6	3·1	2·4
		" 3000	6·95	5·9	3·5	3·3	2·9	2·4	2·5	2·1	1·7
		" 3500	5·1	4·3	2·6	2·45	2·16	1·8	1·84	1·58	1·21
		" 4000	3·9	3·3	2·0	1·9	1·6	1·4	1·4	1·2	0·9

WILLOUGHBY SMITH'S IMPROVED GUTTA-PERCHA.

The specific gravity of gutta-percha prepared by Mr. Willoughby Smith's process is the same as that of ordinary gutta-percha.

The mechanical strength of this material is about 12% greater than that of ordinary gutta-percha.

The electro-static capacity (F) per knot of a core of Smith's G. P. is approximately

$$F = \frac{0{\cdot}15163}{\log \frac{D}{d}} \quad . \quad . \quad \text{microfarads.}$$

$$(\text{Log } 0{\cdot}15163 = 0{\cdot}1807851 - 1).$$

The electro-static capacity of Smith's G. P. core, as compared with Hooper's core of similar size, is as 100 to 98, about.

The resistance (R) per knot, of Smith's G. P. core at 75° F. (= 24° Cent.) is approximately

$$R = 350 \log \frac{D}{d} \quad . \quad . \quad \text{megohms}$$

after one minute's electrification.

The resistance after the 1st minute, of Smith's G. P. at 32° Fahr. is about the same as that of ordinary G. P. After a long application of the battery at this temperature the ratio falls to 72 : 100, about.

The resistance after the 1st minute, of Smith's G. P. at 75° Fahr., compared with that of ordinary G. P., is as 67 to 100; or about 30% inferior.

Table of the relative resistance (after 1 minute) **of Willoughby Smith's improved Gutta-percha** at different temperatures, for all cores in which the thickness of G. P. does not exceed 0·110 inch.—(*W. Smith.*)

Temperature.		Resistance.	Log Resistance.	Temperature.		Resistance.	Log Resistance.
Fahr.	Cent.			Fahr.	Cent.		
32	0·0	27·913	·445807	67	19·4	1·858	·269046
33	0·5	25·834	·412192	68	20·0	1·719	·235276
34	1·1	23·91	·378580	69	20·5	1·591	·201670
35	1·6	22·128	·344942	70	21·1	1·473	·168203
36	2·2	20·48	·311330	71	21·6	1·363	·134496
37	2·7	18·954	·277701	72	22·2	1·261	·100715
38	3·3	17·542	·244079	73	22·7	1·167	·067071
39	3·8	16·235	·210452	74	23·3	1·080	·033424
40	4·4	15·025	·176815	**75**	23·8	**1·000**	·000000
41	5·0	13·906	·143202	76	24·4	·9375	·971971
42	5·5	12·87	·109579	77	25·0	·8789	·943940
43	6·1	11·911	·075948	78	25·5	·8240	·915927
44	6·6	11·024	·042339	79	26·1	·7725	·887899
45	7·2	10·203	·008728	80	26·6	·7242	·859859
46	7·7	9·442	·975064	81	27·2	·6789	·831806
47	8·3	8·739	·941462	82	27·7	·6365	·803798
48	8·8	8·088	·907841	83	28·3	·5967	·775756
49	9·4	7·485	·874192	84	28·8	·5594	·747723
50	10·0	6·928	·840608	85	29·4	·5245	·719746
51	10·5	6·412	·806994	86	30·0	·4917	·691700
52	11·1	5·934	·773348	87	30·5	·4609	·663607
53	11·6	5·492	·739731	88	31·1	·4321	·635584
54	12·2	5·083	·706120	89	31·6	·4051	·607562
55	12·7	4·704	·672467	90	32·2	·3798	·579555
56	13·3	4·354	·638888	91	32·7	·3561	·551572
57	13·8	4·029	·605197	92	33·3	·3338	·523486
58	14·4	3·729	·571592	93	33·8	·3130	·495544
59	15·0	3·451	·537945	94	34·4	·2934	·467460
60	15·5	3·194	·504335	95	35·0	·2751	·439491
61	16·1	2·956	·470704	96	35·5	·2579	·411451
62	16·6	2·736	·437116	97	36·1	·2417	·383277
63	17·2	2·532	·403464	98	36·6	·2266	·355260
64	17·7	2·343	·369772	99	37·2	·2125	·327359
65	18·3	2·169	·336260	100	37·7	·1992	·299289
66	18·8	2·007	·302547				

The resistance (R_t) at any temperature (t°) of Smith's G. P. may be found from its known resistance (R_{24}) at 24° C., after 1 minute, by the formula,

$$\log R_t = \log R_{24} + (0·06447 - 0·00017\,t)\,(24 - t)$$

Table for reducing Resistance of Willoughby Smith's improved Gutta-percha to 24° Cent.

(Resistance after Current has been kept on for one minute.)

LOGARITHMS.					NATURAL NUMBERS.					
Temp. Cels.	Temp. Fahr.	$\text{Log}\ \frac{R_t}{R_{24}}$	$\text{Log}\ \frac{R_{24}}{R_t}$	Diff. for One Deg.	Temp. Cels.	Temp. Fahr.	$\frac{R_t}{R_{24}}$	Diff. for One Deg.	$\frac{R_{24}}{R_t}$	Diff. for One Deg.
1	2	3	4	5	6	7	8	9	10	11
24	75·2	0·0000	0·0000	0·0643	24	75·2	1·000	0·160	1·0000	0·1376
23	73·4	0·0643	$\bar{1}$·9357	·0640	23	73·4	1·160	0·184	0·8624	0·1181
22	71·6	0·1283	$\bar{1}$·8717	·0636	22	71·6	1·344	0·212	0·7443	0·1014
21	69·8	0·1919	$\bar{1}$·8081	·0633	21	69·8	1·556	0·244	0·6429	0·0872
20	68·0	0·2552	$\bar{1}$·7448	·0629	20	68·0	1·800	0·280	0·5557	0·0750
19	66·2	0·3181	$\bar{1}$·6819	·0626	19	66·2	2·080	0·323	0·4807	0·0645
18	64·4	0·3807	$\bar{1}$·6193	·0623	18	64·4	2·403	0·370	0·4162	0·0556
17	62·6	0·4430	$\bar{1}$·5570	·0619	17	62·6	2·773	0·425	0·3606	0·0479
16	60·8	0·5049	$\bar{1}$·4951	·0616	16	60·8	3·198	0·487	0·3127	0·0413
15	59·0	0·5665	$\bar{1}$·4335	·0612	15	59·0	3·685	0·558	0·2714	0·0457
14	57·2	0·6277	$\bar{1}$·3723	·0609	14	57·2	4·243	0·639	0·2357	0·0309
13	55·4	0·6886	$\bar{1}$·3114	·0606	13	55·4	4·882	0·731	0·2048	0·0266
12	53·6	0·7492	$\bar{1}$·2508	·0602	12	53·6	5·613	0·834	0.1782	0·0231
11	51·8	0·8094	$\bar{1}$·1906	·0599	11	51·8	6·447	0·954	0·1551	0·0200
10	50·0	0·8693	$\bar{1}$·1307	·0595	10	50·0	7·401	1·076	0·1351	0·0173
9	48·2	0·9288	$\bar{1}$·0712	·0593	9	48·2	8·487	1·242	0·1178	0·0150
8	46·2	0·9881	$\bar{1}$·0119	·0588	8	46·2	9·729	1·411	0·1028	0·0130
7	44·6	1·0469	$\bar{2}$·9531	·0585	7	44·6	11·14	1·61	0·0898	0·0113
6	42·8	1·1054	$\bar{2}$·8946	·0582	6	42·8	12·75	1·82	0·0785	0·0099
5	41·0	1·1636	$\bar{2}$·8364	·0578	5	41·0	14·57	2·08	0·0686	0·0086
4	39·2	1·2214	$\bar{2}$·7786	·0575	4	39·2	16·65	2·36	0·0601	0·0074
3	37·4	1·2789	$\bar{2}$·7211	·0572	3	37·4	19·01	2·57	0·0526	0·0065
2	35·6	1·3361	$\bar{2}$·6639	·0568	2	35·6	21·68	3·03	0·0461	0·0056
1	33·8	1·3929	$\bar{2}$·6071	·0565	1	33·8	24·71	3·43	0·0405	0·0050
0	32·0	1·4494	$\bar{2}$·5506	·0561	0	32·0	28·14	3·89	0·0355	0·0043
—1	30·2	1·5055	$\bar{2}$·4945	·0558	—1	30·2	32·03	4·38	0·0312	0·0037
—2	28·4	1·5613	$\bar{2}$·4387	·0555	—2	28·4	36·41	4·87	0·0275	0·0033
—3	26·6	1·6168	$\bar{2}$·3832	·0551	—3	26·6	41·38	5·60	0·0242	0·0029
—4	24·8	1·6719	$\bar{2}$·3281	·0548	—4	24·8	46·98	6·31	0·0213	0·0025
—5	23·0	1·7267	$\bar{2}$·2733	·0544	—5	23·0	53·29	7·12	0·0188	0·0022
—6	21·2	1·7811	$\bar{2}$·2189		—6	21·2	60·41		0·0166	

$$\text{Formula} = \text{Log}\ \frac{R_t}{R_{24}} = (0·06447 - 0·00017\,t)\,(24 - t).$$

Table to find Resistance, after 1 minute, and Capacity per Knot of W. Smith's Gutta-percha core, from the relative Weights or Diameters of $\left(\frac{\text{Insulator}}{\text{Conductor}}\right)$.

$\frac{W}{w}$	$\frac{D}{d}$	Resistance per knot at 24° C. in megohms.	Electro-static capacity per knot in micro-farads.	$\frac{W}{w}$	$\frac{D}{d}$	Resistance per knot at 24° C. in megohms.	Electro-static capacity per knot in micro-farads.
1·00	2·80	164	·3238	1·26	3·10	179	·2962
1·01	2·81	164	·3228	1·27	3·11	180	·2947
1·02	2·82	165	·3217	1·28	3·12	181	·2939
1·03	2·83	165	·3207	1·29	3·13	181	·2932
1·04	2·85	166	·3188	1·30	3·14	182	·2924
1·05	2·86	167	·3178	1·31	3·15	182	·2917
1·06	2·87	167	·3171	1·32	3·17	183	·2902
1·07	2·88	168	·3159	1·33	3·18	183	·2895
1·08	2·90	169	·3140	1·34	3·19	184	·2888
1·09	2·91	170	·3122	1·35	3·20	184	·2881
1·10	2·92	170	·3113	1·36	3·21	185	·2874
1·11	2·93	171	·3104	1·37	3·22	185	·2867
1·12	2·94	171	·3095	1·38	3·23	186	·2860
1·13	2·95	172	·3086	1·39	3·24	186	·2853
1·14	2·96	172	·3077	1·40	3·25	186	·2846
1·15	2·98	173	·3060	1·41	3·26	187	·2839
1·16	2·99	174	·3051	1·42	3·27	187	·2833
1·17	3·00	174	·3043	1·43	3·28	188	· 826
1·18	3·01	175	·3035	1·44	3·29	188	·2819
1·19	3·02	175	·3026	1·45	3·30	189	·2806
1·20	3·03	176	·3018	1·46	3·31	189	·2800
1·21	3·04	176	·3010	1·47	3·32	190	·2793
1·22	3·06	177	·2994	1·48	3·33	190	·2787
1·23	3·07	178	·2986	1·49	3·34	191	·2781
1·24	3·08	178	·2978	1·50	3·35	191	·2774
1·25	3·09	179	·2970	1·51	3·36	192	·2768

When the ratio between the weights (*W*) of percha and of copper (*w*) are given, the resistance and capacity of the core are the same, whatever be the absolute value of these weights. The same is true of the relative diameters D and *d*. In using the above table we have only to ascertain the quotient $\frac{\text{weight of percha}}{\text{weight of copper}}$ or the $\frac{\text{diameter of percha}}{\text{diameter of copper}}$ and the table gives by inspection the resistance at 24° Cent. in megohms, and the electro-static capacity in microfarads.

Table of Coefficients for reducing Silvertown Gutta-percha to 75° F. (*F. Hawkins.*)

Temp.	Coefficient.	Log of Coefficient.	Temp.	Coefficient.	Log of Coefficient.
75	1·000	0·0000000	53	5·494	0·7398887
74	1·018	0·0077478	52	5·908	0·7714405
73	1·054	0·0228406	51	6·330	0·8014037
72	1·108	0·0445398	50	6·770	0·8305887
71	1·180	0·0718820	49	7·238	0·8596186
70	1·270	0·1038037	48	7·724	0·8878423
69	1·378	0·1392492	47	8·228	0·9152946
68	1·504	0·1772478	46	8·740	0·9415114
67	1·648	0·2169572	45	9·280	0·9675480
66	1·810	0·2576786	44	9·838	0·9929068
65	1·990	0·2988531	43	10·414	1·0176176
64	2·188	0·3400473	42	11·008	1·0417084
63	2·394	0·3791241	41	11·610	1·0648322
62	2·618	0·4179696	40	12·230	1·0874265
61	2·860	0·4563660	39	12·868	1·1095111
60	3·120	0·4941546	38	13·524	1·1301052
59	3·398	0·5312234	37	14·198	1·1512272
58	3·704	0·5686710	36	14·890	1·1728947
57	4·028	0·6050895	35	15·600	1·1931246
56	4·360	0·6394865	34	16·328	1·2129330
55	4·720	0·6739420	33	17·074	1·2323353
54	5·098	0·7073998	32	17·838	1·2513462

INDIA-RUBBER.

The specific gravity of Hooper's india-rubber compound is about 1·176. One cubic foot of india-rubber compound weighs 73·44 lbs.

The weight of Hooper's india-rubber compound per knot is 1 lb. for every 401 circular mils of sectional area.

The weight of Hooper's india-rubber per knot in any cable is about $\frac{D^2 - d^2}{401}$ lbs. D being the external diameter of the core and *d* that of the conductor.

The weight of Hooper's india-rubber per statute mile

$$= \frac{D^2 - d^2}{462 \cdot 3}.$$

The exterior diameter of any core of Hooper's india-

rubber is $= \sqrt{70{\cdot}4\,w + 401\,W}$; W being the weight in lbs. per knot of the compound, and w that of the copper strand.

The resistance per knot of any core of Hooper's india-rubber is about 15400 (log D − log d) megohms at 75 Fahr.

The resistance per knot of any of Hooper's core at 75° F. is

1. With a solid conductor,

$$15400 \log \sqrt{1 + 7{\cdot}3\,\frac{W}{w}} \text{ megohms.}$$

2. With a strand conductor,

$$15400 \log \left(\sqrt{1 + 5{\cdot}7\,\frac{W}{w}}\right) \text{ megohms.}$$

Where W is the weight of the dielectric and w the weight of the copper.

The electro-static capacity per knot of any core of Hooper's india-rubber is approximately

$$\frac{0{\cdot}1485}{\operatorname{Log} D - \log d} \text{ microfarads.}$$

The electro-static capacity per knot of any core of Hooper's india-rubber is

1. With a solid conductor,

$$\frac{0{\cdot}1485}{\log \sqrt{1 + 7{\cdot}3\,\frac{W}{w}}} \text{ microfarads.}$$

2. With a strand conductor,

$$\frac{0{\cdot}1485}{\log \left(\sqrt{1 + 5{\cdot}7\,\frac{W}{w}}\right)} \text{ microfarads}$$

Resistance (Comparative) of Gutta-percha and Hooper's Insulator, at different Temperatures, showing the Decrease of Resistance due to the Increase of Temperature.

Temperature.		Resistances.			
		Gutta-percha—Persian Gulf Cable.		Hooper's core—Ceylon Cable.	
Centigrade.	Fahrenheit.	Observed.	Calculated.	Observed.	Calculated.
0	32·0	100·00	100·00	100 00	100·00
2	35·6	84·14	80·00	90·10	88·73
4	39·2	64·66	64·00	8[illegible]·60	78·62
6	42·8	47·65	51·20	72·90	68·30
8	46·4	37·15	4[illegible]·96	65·30	61·20
10	50·0	28·97	32·77	58·80	54·81
12	53·6	23·18	26·22	52·90	48·56
14	57·2	16·89	20·97	49·40	43·07
16	60·8	14·37	16·78	44·50	38·18
18	64·4	11·05	13·42	34·60	33·85
20	68·0	8·43	10·74	29·10	30·01
22	71·6	6·82	8·59	26·4[illegible]	26·51
24	75·2	5·51	6·87	24·50	23·59
26	78·8	4·47	5·5[illegible]	22·30	2[illegible]·91
28	82·4	3·51	4·40	18·60	18·55
30	86·0	2·99	3·52	16·[illegible]0	16·44
32	89·6	2·48	2·82	16·00	14·58
34	93·2	1·92	2·26	14·40	12.93
36	96·8	1·68	1·80	13·00	11·46
38	100·4	1·43	1·44	10·60	10·16

The calculated values for gutta-percha are from Messrs. Bright and Clark's published table; those for Hooper's insulator have been furnished by Mr. Hooper.

EFFECTS OF TEMPERATURE ON HOOPER'S MATERIAL.

The rate of variation in its insulation is, according to Mr. Warren's experiments, 0·026 for 1° Fahr. A difference of 27° above any temperature Fahr. reduces its insulation one-half, or the same difference below any temperature increases its insulation twofold, or according to table of coefficients:

When from the resistance at a given temperature, the

resistance corresponding to a *lower* temperature is required, *multiply* the resistance at the given temperature by the number opposite to the degrees of difference. When the correction is required for any higher temperature, *divide* by the number opposite to the degrees of difference, the result in either case is the resistance required.

Coefficients for Temperature corrections for Hooper's Material.—(*Warren.*)

Diffs. of Temp. F.	Logarithms.	Nat. Numbers.	Diffs. of Temp. F.	Logarithms.	Nat. Numbers.
1°	·01115	1·026	26°	·28990	1·949
2	·02230	1·053	27	·30105	2·000
3	·03345	1·080	28	·31220	2·052
4	·04460	1·108	29	·32335	2·105
5	·05575	1·137	30	·33450	2·160
6	·06690	1·167	31	·34565	2·216
7	·07805	1·197	32	·35680	2·274
8	·08920	1·228	33	·36795	2·333
9	·10035	1·260	34	·37910	2·394
10	·11150	1·293	35	·39025	2·456
11	·12265	1·326	36	·40140	2·520
12	·13380	1·361	37	·41255	2·586
13	·14495	1·396	38	·42370	2·653
14	·15610	1·433	39	·43485	2·722
15	·16725	1·470	40	·44600	2·796
16	·17840	1·508	41	·45715	2·865
17	·18955	1·547	42	·46830	2·940
18	·20070	1·587	43	·47945	3·016
19	·21185	1·629	44	·49060	3·091
20	·22300	1·671	45	·50175	3·175
21	·23415	1·715	46	·51290	3·258
22	·24530	1·759	47	·52405	3·342
23	·25645	1·805	48	·53520	3·429
24	·26760	1·852	49	·54635	3·518
25	·27875	1·900	50	·55750	3·610

Example.—A length of Hooper's core at 60° Fahr. was found to have an insulation resistance of 16124 megohms. Its resistance at 75° Fahr. is therefore

$$\frac{16124}{1{\cdot}470} = 10968 \text{ megohms.}$$

Relative Resistance of Hooper's Material at different Temperatures.— (*Warren.*)

Temp. Fahr.	Resistance.	Temp. Fahr.	Resistance.	Temp. Fahr.	Resistance.
32°	301·6	56°	162·9	80°	87·95
33	294·0	57	158·7	81	85·72
34	286·5	58	154·7	82	83·55
35	279·6	59	150·8	83	81·44
36	272·2	60	147·0	84	79·37
37	265·3	61	143·3	85	77·36
38	258·6	62	139·6	86	75·40
39	252·0	63	136·1	87	73·49
40	245·6	64	132·6	88	71·62
41	239·4	65	129·3	89	69·81
42	233·3	66	126·0	90	68·04
43	227·4	67	122·8	91	66·31
44	221·6	68	119·7	92	64·63
45	216·0	69	116·7	93	62·99
46	210·5	70	113·7	94	61·40
47	205·2	71	110·8	95	59·84
48	200·0	72	108·0	96	58·32
49	194·9	73	105·3	97	55·41
50	190·0	74	102·6	98	54·00
51	185·2	**75**	**100·00**	99	52·63
52	180·5	76	97·46	100	51·30
53	175·9	77	95·00	101	50·00
54	171·5	78	92·59	134	25·00
55	167·1	79	90·34		

The resistance of a cube FOOT of Hooper's material,
$= 249 \times 10^6$ megohms at 75° F.

Its electro-static capacity $= 8·92 \times 10^{-6}$ microfarads.

The resistance of a cube KNOT of Hooper's material,
$= 40950$ megohms at 75° F.

Its electro-static capacity = 0·0543 microfarads.

A PLATE of Hooper's material, 1 square foot surface and 1 *mil* thick, has a

Resistance = 20770 ohms at 75° F.

Its electro-static capacity = 0·1073 microfarads.

The insulation resistance (in megohms, at 75° F.) of any perfect cable or condenser of Hooper's material multiplied by its electro-static capacity in microfarads = 2220.

TABLE to find Resistance, after 1 minute, and Capacity per Knot of any Hooper's Core from the relative Weights or Diameters of $\left(\frac{\text{Insulator}}{\text{Conductor}}\right)$.

$\frac{W}{w}$	$\frac{D}{d}$	Resistance per knot at 24° C. in megohms.	Electro-static capacity per knot in micro-farads.	$\frac{W}{w}$	$\frac{D}{d}$	Resistance per knot at 24° C. in megohms.	Electro-static capacity per knot in micro-farads.
0·85	2·42	6072	·3669	1·11	2·71	6822	·3266
0·86	2·43	6098	·3652	1·12	2·72	6846	·3254
0·87	2·44	6124	·3639	1·13	2·73	6869	·3244
0·88	2·45	6149	·3624	1·14	2·74	6891	·3233
0·89	2·46	6174	·3609	1·15	2·75	6914	·3223
0·90	2·48	6225	·3580	1·16	2·76	6936	·3212
0·91	2·49	6259	·3565	1·17	2·77	6959	·3202
0·92	2·50	6299	·3537	1·18	2·78	6981	·3192
0·93	2·51	6324	·3523	1·19	2·79	7004	·3182
0·94	2·52	6359	·3501	1·20	2·80	7026	·3172
0·95	2·53	6373	·3496	1·21	2·81	7047	·3162
0·96	2·54	6398	·3482	1·22	2·82	7070	·3152
0·97	2·56	6446	·3456	1·23	2·83	7092	·3142
0·98	2·57	6470	·3444	1·24	2·84	7113	·3132
0·99	2·58	6495	·3431	1·25	2·85	7137	·3123
1·00	2·59	6518	·3418	1·26	2·86	7157	·3113
1·01	2·60	6543	·3406	1·27	2·87	7179	·3104
1·02	2·61	6566	·3394	1·28	2·88	7200	·3095
1·03	2·62	6590	·3381	1·29	2·89	7221	·3085
1·04	2·63	6614	·3369	1·30	2·90	7265	·3067
1·05	2·64	6638	·3357	1·31	2·91	7281	·3058
1·06	2·65	6660	·3345	1·32	2·92	7307	·3049
1·07	2·67	6708	·3322	1·33	2·93	7328	·3040
1·08	2·68	6731	·3310	1·34	2·94	7349	·3032
1·09	2·69	6755	·3299	1·35	2·95	7370	·3023
1·10	2·70	6800	·3277	1·36	2·96	7391	·3015

When the ratio between the weights (W) of rubber and of copper (w) are given, the resistance and capacity of the core are the same, whatever be the absolute value of these weights. The same is true of the relative

diameters D and *d*. In using the above table we have only to ascertain the quotient $\frac{\text{weight of rubber}}{\text{weight of copper}}$ or the $\frac{\text{diameter of rubber}}{\text{diameter of copper}}$ and the table gives by inspection the resistance at 24° Cent. in megohms, and the electro-static capacity in microfarads.

VULCANITE.

Vulcanite, when pure, should consist only of india-rubber and sulphur. Its specific gravity is about 1·31. It should present a clean conchoidal surface when broken; a granular fracture is due to admixture of other materials. Its surface, when polished, should be free from specks or indentations. By friction with a black silk rubber, it becomes strongly excited with negative electricity, which in a dry atmosphere it should retain for some hours. In thin strips it is very elastic, and when heated it may be bent and will retain its new shape or form permanently when cooled.

The surface of vulcanite becomes conducting, partly by the condensation of moisture, and a slight film of sulphurous acid, which is produced by the oxidation of sulphur. On this account, all vulcanite supports and connections should be repeatedly washed with boiling water, and rinsed well in distilled water, and dried. This

is the most effectual way of dealing with vulcanite apparatus when found leaky, as friction will not remove entirely the film of acid. It is, however, better to keep its surface varnished with shellac.

HEMP.

In a cable, as ordinarily applied in serving—

One cubic foot of (Russian or Italian) hemp weighs about 39 lbs.

One cubic foot of tarred hemp weighs about 56 lbs.

One cubic foot of Manilla weighs about 41 lbs.

The number of cubic inches of hemp space divided by one of the following constants gives approximately the weight of hemp in lbs.

Italian or Russian . . .	44
Tarred hemp	30
Manilla	41

The transverse area of the hemp section in a cable, in square inches, multiplied by one of the following constants, gives approximately the weight of hemp serving, per knot, in cwts.

Italian or Russian	14
Tarred hemp	21
Manilla	15

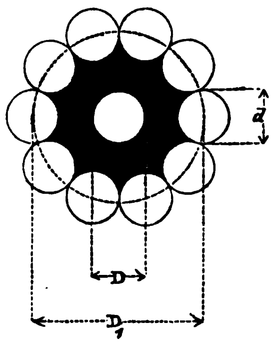
The weight of hemp serving *in a cable.*

Let D_1 be the diameter of the centre line of the iron wires, in inches (see Table, page 149);

D the diameter of the dielectric in inches;

d the diameter of a single iron wire also in inches; and

n the number of iron wires.



Then

The transverse sectional area of the hemp is

$$0{\cdot}7854\left(D_1^2 - D^2 - \frac{n}{2}d^2\right) \text{ square inches.}$$

And the weight, per knot, of serving is approximately as follows:

Hemp . . . $12\left(D_1^2 - D^2 - \frac{n}{2}d^2\right)$ cwt.

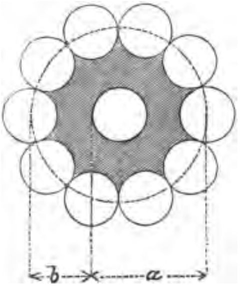
Tarred hemp . $17\left(D_1^2 - D^2 - \frac{n}{2}d^2\right)$ cwt.

Manilla . . . $13\left(D_1^2 - D^2 - \frac{n}{2}d^2\right)$ cwt.

Another way.

Let the diameter of the centre line of the wires be divided into the two parts a and b (in inches) by the exterior of the core on one side.

d = the diameter of the iron wire in inches.



Then **the sectional area of the hemp is**

$$3{\cdot}14\left(a\,b - \frac{n}{8}\,d^2\right) \text{ square inches.}$$

And **the weight per knot of serving** is approximately as follows :

Hemp . . . . $46\left(a\,b - \frac{n}{8}\,d^2\right)$ cwt.

Tarred hemp . . . . $66\left(a\,b - \frac{n}{8}\,d^2\right)$ cwt.

Manilla . . . . . . $50\left(a\,b - \frac{n}{8}\,d^2\right)$ cwt.

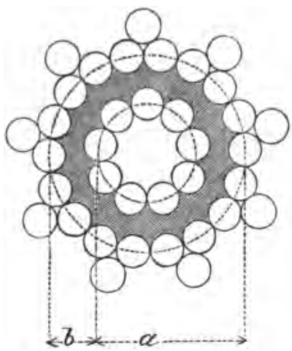
To find the weight of hemp serving between two ring-sections of iron wires.

Let the diameter of the centre line of the outer ring be

divided by one side of the centre line of the inner ring of wires in the two parts a and b (in inches).

n be the number of wires in the inner ring, each of d (inches) diameter; and

m be the number of iron wires in the outer ring, each having a diameter of d_1 (inches).



Then the area of the hemp section is

$$3{\cdot}14\left(a\,b - \frac{m\,d_1^2 + n\,d^2}{8}\right) \text{ square inches.}$$

And the weight of hemp per knot is approximately as follows:

Hemp . . . $46\left(a\,b - \frac{m\,d_1^2 + n\,d^2}{8}\right)$ cwt.

Tarred hemp . $66\left(a\,b - \frac{m\,d_1^2 + n\,d^2}{8}\right)$ cwt.

Manilla . . . $50\left(a\,b - \frac{m\,d_1^2 + n\,d^2}{8}\right)$ cwt.

Ropes of hemp are laid in both 3 and 4 strands of twisted fibres and run to a diameter of 4 inches.

Hawsers are laid with either 3 ropes or with 4 strands.

Cables are only laid with 3 strands of rope.

Newly tarred ropes are 25% weaker than white ropes. This is caused partly by reason of the injury done to the fibre by the hot tar, and partly by the tar acting as a lubricator between the fibres.

Tarred hemp and manilla ropes are of about equal strength.

Manilla ropes hold 25 to 30% less than white ropes.

The absorption of tar in weight is as follows :—

Bolt rope . . .	18	per cent.
Shrouding .	15 to 18	do.
Cables	21	do.
Spun yarn .	25 to 30	do.

IRON.

The specific gravity *of bar iron* is about 7·79. One cubic foot weighs about 480 lbs. One cubic inch weighs 0·28 lbs.

The breaking weight of the commonest iron rod is 20 to 25 tons per square inch section; the breaking weight of drawn wires is very much greater, increasing as the wire is finer up to 40 and 50 tons per square inch. Hard drawn wires are much stronger than annealed or rolled, and the strength varies greatly with quality; no general rule for strength can therefore be given.

The weights in the table at page 142 are calculated on the assumption that 1 cubic foot of iron weighs 481 lbs.

The weight *of any iron wire* per nautical mile is $\frac{d^2}{62 \cdot 6}$ lbs. (d being its diameter in mils).

The weight of any iron wire per statute mile is $\frac{d^2}{72}$ lbs.

The diameter of any iron wire weighing w lbs. per statute mile $= 8 \cdot 49 \sqrt{w}$ . . mils.

The diameter of any iron wire weighing w lbs. per nautical mile $= 7 \cdot 91 \sqrt{w}$ . . mils.

The conductivity of ordinary galvanized iron wire averages about $\frac{1}{7}$th that of pure copper.

The resistance per statute mile of a galvanized iron wire is about $\frac{360{,}000}{d^2}$ ohms, at 60° Fahr.

The resistance of No. 8 iron wire is about one ohm per hundred yards length.

The resistance of iron increases about 0·39 per cent. for each degree Fahr.

The weight of iron per nautical mile in any submarine cable is approximately $\frac{d^2 n}{6806}$ cwt., where d = the diameter of the wire in mils, and n the number of wires.

The diameter of any submarine cable is as follows :— Let D = diameter of cable, d that of the wire covering it, n the number of wires ; then

$$D = d \times \left(1 + \text{cosecant } \frac{180^\circ}{n}\right);$$

or, approximately, $D = \frac{d \times (n \times 3.2)}{3.14}$.

TABLE of the Weight of Iron per Nautical Mile in Cables of different Sizes. Including 3 per cent. for lay.

Size of Wire B. W. G.	Diameter in Mils.	NUMBER OF WIRES IN CABLE.									
		9	10	11	12	13	14	15	16	17	18
		Cwt.	Cwt.	Cwt.	Cwt.	Cwt.	Cwt.	Cwt.	Cwt.	Cwt.	Cwt.
00	380	191	212	233	254	276	297	318	339	360	382
0	340	153	170	187	204	251	238	255	271	289	305
1	300	119	132	145	158	172	185	198	211	224	238
2	284	107	118	130	142	153	166	177	189	201	213
3	259	89	98	108	118	127	138	147	157	167	177
4	238	75	83	91	100	108	116	125	133	141	149
5	220	64	71	78·1	85	92·3	100	107	114	121	128
6	203	54	60	66·0	72	78·0	85	90·0	97	102	109
7	180	43	47	51·7	57	61·1	66	70·5	76	79·9	85
8	165	35·8	39·8	43·8	47·7	51·7	55·7	59·7	63·6	67·7	71·6
9	148	28·9	32·1	35·3	38·6	41·7	45·0	48·2	51·4	54·6	57·8
10	134	23·6	26·3	28·9	31·5	34·2	36·8	39·5	42·0	44·7	47·3
11	120	19·0	21·1	23·2	25·3	27·4	29·6	31·7	33·8	35·9	38·0
12	109	15·6	17·3	19·0	20·8	22·5	24·2	26·0	27·7	29·4	31·2
13	95	11·9	13·2	14·5	15·8	17·2	18·5	19·8	21·1	22·4	23·7
14	83	9·6	10·1	11·1	12·1	13·1	14·1	15·2	16·2	17·2	18·2
15	72	6·8	7·5	8·3	9·0	9·8	10·5	11·3	12·0	12·8	13·5
16	65	5·5	6·1	6·7	7·3	7·9	8·5	9·2	9·7	10·4	10·9

TABLE of the Sizes and Weights of Iron Wire.

Size of Wire B. W. G.	Diam. in Mils.	PER STATUTE MILE. Weight in Lbs.	Weight in Cwts.	Resistance in Ohms.	Nautical Mile Weight in Cwts.	Breaking Weight at 20 Tons per sq. in.
1 sq. in.	..	17645	157·54	0·340	181·63	4000·
1 circ. in.	1000	13858	123·73	0·433	142·65	314·16
0000	454	2854	25·48	2·10	29·38	64·40
000	425	2502	22·33	2·40	25·75	56·40
00	380	2001	17·86	3·00	20·59	45·36
0	340	1600	14·28	3·74	16·47	36·31
1	300	1245	11·12	4·81	12·82	28·27
2	284	1117	9·97	5·37	11·49	25·33
3	259	928	8·28	6·46	9·55	20·07
4	238	783	6·99	7·65	8·06	17·79
5	220	670	5·98	8·96	6·90	15·20
6	203	570	5·09	10·52	5·86	12·94
7	180	448	4·00	13·38	4·61	10·17
8	165	376	3·35	16·39	3·86	8·55
9	148	303	2·71	19·79	3·12	6·88
10	134	249	2·22	24·14	2·55	5·64
11	120	199	1·78	30·10	2·05	4·52
12	109	164	1·46	36·49	1·68	3·73
13	95	124	1·11	48·01	1·28	2·83
14	83	95	0·85	62·93	0·98	2·16
15	72	72	0·64	83·65	0·73	1·62
16	65	58	0·52	102·6	0·59	1·32
17	58	46·38	..	..	..	..
18	49	33·17	..	..	..	..
19	42	24·35	..	..	..	..
20	35	17·93	..	..	..	..
21	32	14·11	..	..	..	..
22	28	10·76	..	..	..	..

TABLE of the External Diameter of Submarine Cables.

Sizes B. W. G.	Diam. in Mils.	NUMBER OF WIRES.									
		9	10	11	12	13	14	15	16	17	18
00	380	1·491	1·607	1·729	1·848	1·967	2·089	2·208	2·328	2·446	2·568
0	340	1·334	1·440	1·547	1·654	1·760	1·869	1·975	2·084	2·188	2·298
1	300	1·177	1·271	1·365	1·459	1·553	1·649	1·743	1·838	1·931	2·028
2	284	1·114	1·203	1·292	1·381	1·470	1·561	1·649	1·740	1·828	1·919
3	259	1·017	1·097	1·178	1·260	1·341	1·424	1·505	1·587	1·667	1·751
4	238	0·934	1·008	1·037	1·157	1·232	1·308	1·383	1·458	1·533	1·608
5	220	0·863	0·932	1·011	1·070	1·139	1·209	1·278	1·348	1·417	1·487
6	203	0·796	0·860	0·924	0·987	1·051	1·116	1·179	1·243	1·307	1·372
7	180	0·706	0·762	0·819	0·875	0·932	0·989	1·046	1·103	1·158	1·217
8	165	0.647	0·699	0·751	0·802	0·854	0·907	0·959	1·010	1·062	1·115
9	148	0·581	0·627	0·673	0·720	0·766	0·813	0·860	0·907	0·953	1·000
10	134	0·526	0·567	0·610	0·653	0·693	0·736	0·779	0·821	0·862	0·906
11	120	0·471	0·508	0·546	0·584	0·621	0·660	0·697	0·735	0·772	0·811
12	109	0·428	0·462	0·496	0·530	0·563	0·599	0·633	0·668	0·702	0·737
13	95	0·373	0·402	0·432	0·462	0·492	0·522	0·552	0·582	0·611	0·642
14	85	0·326	0·352	0·378	0·403	0·430	0·456	0·482	0·508	0·534	0·561
15	72	0·282	0·305	0·328	0·350	0·373	0·396	0·417	0·441	0·463	0·487
16	65	0·255	0·275	0·296	0·316	0·317	0·357	0·378	0·398	0·418	0·439
$1 + \text{Cosec.}$	$\frac{180^\circ}{n}$	3·9238	4·2360	4·5506	4·8637	5·1774	5·4964	5·8097	6·1258	6·4362	6·7588

Stranded Wires.

When 3 or 4 wires are twisted together to form a strand, as in the outer wires of very heavy shore end cables, and in the cores of multiple cables, it is sometimes necessary to know the space they occupy.

When 3 wires are used, the diameter of each being 1, the diameter of the circumscribing circle is 2·155.

When 4 wires are laid together the diameter of the circumscribing circle is 2·414.

When 7 wires are used it is 3.

IRON WIRE (Culley).

B. W. Gauge.	Diameter		Area of Section, square inches.	Weight of 100 yards.	Weight of 1760 yards.	Weight of 2029 yards.	Length of 1 cwt.	Breaking Strain.		B. W. Gauge.
	Inches.	Millimetres.						Soft Wire.	Hard Wire.	
				lbs.	lbs.					
00	0·363	9·21	0·103	102·00	1794	2068	110	8600	6000	00
0	0·331	8·40	0·086	84·72	1490	1718	132	7100	4750	0
1	0·300	7·61	0·071	88·75	1210	1395	162	6000	4000	1
2	0·280	7·11	0·062	59·90	1054	1215	187	4850	3400	2
3	0·260	6·60	0·053	51·65	909	1048	215	4000	2900	3
4	0·240	6·10	0·045	44·00	775	895	255	3400	2500	4
5	0·220	5·59	0·038	37·00	651	750	303	2950	2200	5
6	0·200	5·08	0·031	30·56	538	610	361	2500	1800	6
7	0·185	4·69	0·0265	26·15	461	531	428	2200	1520	7
8	0·170	4·31	0·023	22·10	389	448	509	1750	1200	8
9	0·155	3·93	0·0195	18·36	323	373	609	1500	950	9
10	0·140	3·55	0·016	14·97	264	305	747	1200	820	10
11	0·125	3·17	0·0125	11·95	211	244	939	820	650	11
12	0·110	2·79	0·010	9·24	163	188	1244	710	510	12
13	0·095	2·41	0·0071	7·05	124	143	1589	640	400	13
14	0·085	2·15	0·0057	5·51	97	112	2031	510	350	14
15	0·075	1·92	0·0044	4·29	76	87	2608	410	300	15
16	0·065	1·65	0·0033	3·22	57	66	3473	350	200	16
17	0·057	1·44	0·0026	2·48	44	50	4515	280	150	17
18	0·050	1·27	0·0020	1·91	34	39	5600	200	115	18
19	0·045	1·14	0·0016	1·55	27	31	7246	150	85	19
20	0·040	1·01	0·0013	1·22	21	24	9168	110	65	20
21	0·035	0·88	0·0010	0·94	17	20	11980	85	50	21
22	0·030	0·76	0·0007	0·69	12	14	16300	65	40	22

The *breaking strains* of iron wire were supplied by

Messrs. Johnson and Nephew, of Manchester: the *soft wire* is that manufactured expressly for telegraphic purposes.

Specification for Iron Wire. Wire supplied to the Electric Telegraph Company.

The wire to be highly annealed, and very soft and pliable; it is not required to possess great tensile strength, but must be capable of elongating 18 per cent. without breaking after being galvanized.

To be supplied in not less than — lbs. pieces, and to be warranted not to contain any weld, join, or splice whatsoever, and to be free from all imperfections, flaws, sand splits, and other defects.

The whole of the wire to be passed under and over three or more studs or pulleys placed in two lines—the wire passing over the pulleys in the upper line and under the others.

The whole of the wire to be stretched 2 per cent. by machinery in the presence of the company's engineer or his representative, and to be tested, examined, and approved by him before leaving the works. The wire after being stretched to be coiled carefully, so as to contain no bends, but to resemble newly drawn wire in its straightness.

If, during the process of testing the wire between the studs or pulleys, or during the process of stretching it, more than 5 per cent. of the bundles break, crack, or show any defect, the whole of the broken bundles to be rejected. If less than 5 per cent. prove defective, the

wire will be accepted. The makers are not to attempt to weld, join, or otherwise splice any wire that may break or prove defective, but deliver it as it comes from the testing.

Binding.—No. 16 charcoal wire best. When No. 4 wire is used for line, two servings required, and Culley remarks that it is necessary that the turns of the binding round the main wire should be all in one direction.

CLARK'S COMPOUND.

1 cubic inch of asphalte covering weighs (approx.) 0·07 lb.

Clark's compound for the outer casing of the iron sheathing of cables is composed of about

$$\left.\begin{array}{ll} 65 & \text{parts of mineral pitch} \\ 30 & \text{of silica} \\ 5 & \text{of tar} \end{array}\right\} \text{by weight.}$$

This is laid on with coarse hemp; the proportion of hemp to bituminous compound being as 1 to 2 in bulk, nearly.

The specific gravity of solid pitch is 1·65; one cubic foot weighing about 103 lbs.

The specific gravity of silica is 1·7; one cubic foot weighing about 106 lbs.

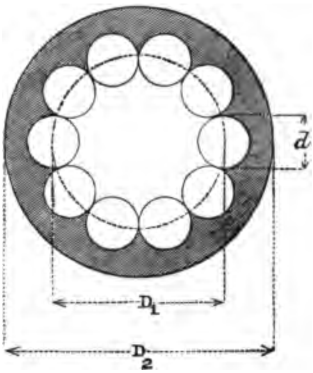
The specific gravity of tar is 1·02; one cubic foot weighing about 63½ lbs.

The specific gravity of Clark's compound varies according to the proportions; one cubic foot of it weighing about 100 lbs.

The transverse area of asphalted section in a cable, in

inches, multiplied by 36, gives (approx.) the weight in cwts. of the asphalte covering per knot length.

To find the weight of hemp and asphalte casing (Clark's compound).



Let D_2 be the exterior diameter, in inches;

D_1 the diameter of the centre line of the iron wires in inches (see Table, page 149);

d the diameter of the iron wire in inches; and

n the number of iron wires.

Then

The transverse sectional area of the asphalte casing is

$$0{\cdot}785\left(D_2^2 - D_1^2 - \frac{n}{2}\,d^2\right) \text{ square inches.}$$

And the weight, per knot, of casing is approximately

$$28{\cdot}\left(D_2^2 - D_1^2 - \frac{n}{2}\,d^2\right) \text{ cwt.}$$

Another way.

Let a and b (in inches) be the two parts into which the

exterior diameter of the cable is divided by the centre line of the iron wires on one side; and

d the diameter, in inches, of a single iron wire.

Then the transverse sectional area of the casing is

$$3{\cdot}14\left(a\,b - \frac{n}{8}\,d^2\right) \text{ square inches.}$$

And the weight, per knot, of casing is approximately

$$112\left(a\,b - \frac{n}{8}\,d^2\right) \text{ cwt.}$$

Chatterton's Compound.

The compound, by means of which the alternate coatings of gutta-percha upon a cable conductor are cemented together, is composed of the following ingredients:—

Stockholm tar . . .	1 part	by weight.
Resin	1 "	
Gutta-percha . . .	3 parts	

This compound is used also for filling up the interstices of strand conductors.

Its specific gravity is about the same as that of ordinary gutta-percha; its insulating capacity, however, is much less.

TABLE of diameters of centre lines of Sheathing Wires for calculating weights of hemp serving and asphalte casing.

Sizes No. B.W.G.	Diameter of single Iron Wires.	NUMBER OF IRON WIRES.									
		9	10	11	12	13	14	15	16	17	18
	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.
00	0·380	1·111	1·227	1·349	1·468	1·587	1·709	1·828	1·948	2·066	2·188
0	0·340	0·994	1·100	1·207	1·314	1·420	1·529	1·535	1·744	1·848	1·958
1	0·300	0·877	0·971	1·065	1·159	1·253	1·349	1·443	1·538	1·631	1·728
2	0·284	0·830	0·919	1·008	1·097	1·186	1·277	1·365	1·456	1·544	1·635
3	0·259	0·758	0·838	0·919	1·001	1·082	1·165	1·246	1·328	1·408	1·492
4	0·238	0·696	0·770	0·799	0·919	0·994	1·070	1·145	1·220	1·295	1·370
5	0·220	0·643	0·712	0·791	0·850	0·919	0·989	1·058	1·128	1·197	1·267
6	0·203	0·593	0·657	0·721	0·784	0·848	0·913	0·976	1·043	1·104	1·169
7	0·180	0·526	0·582	0·639	0·695	0·752	0·809	0·866	0·923	0·978	1·037
8	0·165	0·482	0·534	0·586	0·637	0·689	0·742	0·794	0·845	0·897	0·950
9	0·148	0·333	0·479	0·525	0·572	0·618	0·665	0·712	0·759	0·805	0·852
10	0·134	0·392	0·433	0·456	0·519	0·559	0·602	0·645	0·687	0·728	0·772
11	0·120	0·351	0·388	0·426	0·464	0·501	0·540	0·577	0·615	0·652	0·691
12	0·109	0·319	0·353	0·387	0·421	0·454	0·490	0·524	0.559	0·593	0·628
13	0·095	0·278	0·307	0·337	0·367	0·397	0·427	0·457	0.487	0·516	0·547
14	0·083	0·243	0·269	0·295	0·320	0·347	0·373	0·399	0.425	0·451	0·478
15	0·072	0·210	0·233	0·256	0·278	0·301	0·324	0·345	0.369	0·391	0·415
16	0·065	0·160	0·210	0·231	0·251	0·252	0·292	0·313	0.333	0·353	0·374

SUBMERSION OF CABLES.

Approximate velocity of sinking.

$$v = 2{\cdot}51 \sqrt{d\left(\frac{s'}{s} - 1\right)} \quad . \quad . \quad . \quad . \text{ feet per second.}$$

v = the velocity with which a cable descends towards the bottom, at ordinary angles.

d = the diameter of the cable, in inches.

s = the specific gravity of sea water = 1·028.

s' = the specific gravity of the cable.

Example.—Atlantic cable. Diam. = 1·128"; specific gravity = 1·6. Rate of sinking therefore

$$v = 2{\cdot}51 \sqrt{1{\cdot}128\left(\frac{1{\cdot}6}{1{\cdot}028} - 1\right)} = 1{\cdot}98 \text{ feet per second.}$$

Angle of descent (a°) with the horizon.

$$\frac{v}{V} = \sin a^\circ$$

v = the velocity, in feet per second, with which the cable sinks.

V = the velocity, in feet per second, of the ship.

a° = the angle sought.

Example.—A cable falls freely in sea water at the rate of 1·78 feet per second. Vessel sails 10·4 feet per second (average). Therefore

$$\frac{1{\cdot}78}{10{\cdot}4} = 0{\cdot}17115 = \sin 9^\circ\ 50' \text{ (the angle of descent).}$$

Tension on cable when paying out stopped.

$$t' = {\cdot}0536 \frac{hw}{1 - \cos\beta} \quad . \quad . \quad . \quad . \quad \text{(cwt).}$$

t' = tension on cable hanging over stern.

h = depth in fathoms.

w = weight of a foot of cable in water in lbs.

β = angle of cable (hanging in water, with the horizon).

Example.—Atlantic (1866), h = 2000 fathoms; w = ·242 lbs.; $\beta = 45^\circ$, and another time 90°.

$$1)\quad t' = \cdot 0536 \times \frac{2000 \times \cdot 242}{1 - \cdot 707} = 36\cdot 7 \text{ cwt.}$$

$$2)\quad t' = \cdot 0536 \times \frac{2000 \times \cdot 242}{1 - 0} = 25\cdot 9 \text{ cwt.}$$

Tension of cable when payed out at different angles. (*Airy.*)

Angle made by the cable at the ship with the horizontal line.	Tension of the cable at the ship, expressed in terms of the minimum tension.
5°	262·8
10	65·8
15	29·4
20	16·6
25	10·7
30	7·47
35	5·53
40	4·27
45	3·47
50	2·80
55	2·35
60	2·00

The unit is the weight in water of a piece of cable whose length is equal to the depth of the sea.

To ascertain roughly during submersion the amount of Slack.

$$\text{Slack} = \left(\frac{6000}{st} - 100\right) \text{ per cent.}$$

t = time in minutes of one knot going out.

s = speed of ship in knots per hour by log line.

Example.—In paying out the Atlantic, a knot passed out in 10·2 minutes, whilst the speed of the ship was 5·4 knots. Slack therefore

$$\left(\frac{6000}{11\cdot 2 \times 6\cdot 4} - 100\right) = (109 - 100) = 9 \text{ per cent.}$$

TABLE for ascertaining Slack during paying out.

	SPEED OF SHIP (knots per hour).																
Slack %	3¼ knots.	3¾ knots.	4 knots.	4¼ knots.	4½ knots.	4¾ knots.	5 knots.	5¼ knots.	5½ knots.	5¾ knots.	6 knots.	6¼ knots.	6½ knots.	6¾ knots.	7 knots.	7¼ knots.	Slack %
	CABLE GOES OUT (knots per hour).																
1	3·54	3·80	4·04	4·29	4·55	4·80	5·05	5·30	5·56	5·81	6·06	6·32	6·57	6·82	7·07	7·32	1
2	3·57	3·83	4·08	4·34	4·59	4·85	5·10	5·36	5·61	5·87	6·12	6·38	6·63	6·89	7·14	7·40	2
3	3·61	3·87	4·12	4·38	4·64	4·89	5·15	5·41	5·67	5·92	6·18	6·44	6·70	6·95	7·21	7·47	3
4	3·64	3·90	4·16	4·42	4·68	4·94	5·20	5·46	5·72	5·98	6·24	6·50	6·76	7·02	7·28	7·54	4
5	3·68	3·94	4·20	4·46	4·73	4·99	5·25	5·51	5·78	6·04	6·30	6·56	6·83	7·09	7·35	7·61	5
6	3·71	3·98	4·24	4·51	4·77	5·04	5·30	5·57	5·83	6·10	6·36	6·63	6·89	7·16	7·42	7·69	6
7	3·75	4·02	4.28	4·55	4·82	5·08	5·35	5·62	5·89	6·15	6·42	6·69	6·96	7·22	7·49	7·76	7
8	3·78	4·05	4·32	4·59	4·86	5·13	5·40	5·67	5·94	6·21	6·48	6·75	7·02	7·29	7·56	7·83	8
9	3·82	4·09	4·36	4·63	4·91	5·18	5·45	5·72	6·00	6·27	6·54	6·81	7·09	7·36	7·63	7·90	9
10	3·85	4·13	4·40	4·68	4·95	5·23	5·50	5·78	6·05	6·33	6·60	6·88	7·15	7·43	7·70	7·98	10
11	3·89	4·16	4·44	4·72	5·00	5·27	5·55	5·83	6·11	6·38	6·66	6·94	7·22	7·49	7·77	8·05	11
12	3·92	4·20	4·48	4·76	5·04	5·32	5·60	5·88	6·16	6·44	6·72	7·00	7·28	7·56	7·84	8·12	12
13	3·96	4·24	4·52	4·80	5·09	5·37	5·65	5·93	6·22	6·50	6·78	7·06	7·35	7·63	7·91	8·19	13
14	3·99	4·28	4·56	4·85	5·13	5·42	5·70	5·99	6·27	6·56	6·84	7·13	7·41	7·70	7·98	8·27	14
15	4·03	4·31	4·60	4·89	5·18	5·46	5·75	6·04	6·33	6·61	6·90	7·19	7·48	7·76	8·05	8·35	15
16	4·06	4·35	4·64	4·93	5·22	5·51	5·80	6·09	6·38	6·67	6·96	7·25	7·54	7·83	8·12	8·41	16
17	4·10	4·39	4·68	4·97	5·27	5·56	5·85	6·14	6·44	6·73	7·02	7·31	7·61	7·90	8·19	8·48	17
18	4·13	4·43	4·72	5·02	5·31	5·61	5·90	6·20	6·49	6·79	7·08	7·38	7·67	7·97	8·26	8·56	18
19	4·17	4·46	4·76	5·06	5·36	5·65	5·95	6·25	6·55	6·84	7·14	7·44	7·74	8·03	8·33	8·63	19
20	4·20	4·50	4·80	5·10	5·40	5·70	6·00	6·30	6·60	6·90	7·20	7·50	7·80	8·10	8·40	8·70	20

Strain during Submersion * (t). (*Longridge.*)

$$t = 0{\cdot}0536.\ h\left\{w - \frac{k\,v^2\left(\frac{v}{v'} - \cos a\right)^2}{\sin a}\right\} \quad . \quad . \quad . \text{ in cwts.}$$

h = the depth in fathoms.
w = the weight, *in water*, of one foot of cable in lbs.
v = the velocity, in feet per second, with which the cable leaves the ship.
v' = the velocity of the ship, in feet, per second.
a = the angle which the cable makes with the surface.
k = the so-called coefficient of friction, that is, the resistance, in lbs., which the water opposes to the motion of each foot of cable drawn lengthways, at a speed of one foot a second. For the (1866) Atlantic cable, which was covered with hemp, $k = 0{\cdot}0085$.†

Example.—The (1866) Atlantic deep-sea cable. Depth 2000 fathoms. Weight of one foot in water = ·2576 lbs. Velocity of cable running out = 12 feet per second. Velocity of ship = 10·4 feet per second. k = 0·0085 lbs. And the angle under which the cable entered the water = 9° 30′,

$$t = 0{\cdot}0536 \times 2000\left\{{\cdot}2576 - \frac{{\cdot}0085 \times 10{\cdot}4^2\left(\frac{12}{10{\cdot}4} - {\cdot}9863\right)^2}{{\cdot}16504}\right\} = 10{\cdot}8 \text{ cwt.}$$

* See also Tables, pp. 248, 250.
† For hemp covered cables $k = 0{\cdot}007\,d$
iron covered ,, $k = 0{\cdot}001\,d$
approximately.
d being the diameter in inches.

Approximate Capacity of Cable Tanks.

Let C = circumference of tank in feet;

c = circumference of eye in feet;

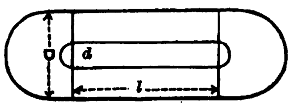
n = number of turns between eye and circumference.

then

$$\frac{(C + c) \times n}{2} = \text{feet of cable in each flake.}$$

½ number of rings × (circumference of tank + circumference of eye) = length in each flake.

In a tank with straight sides and circular ends, the

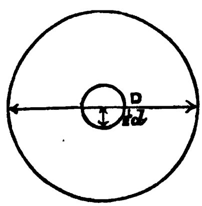


length in each flake is $= n\left(2\,l + \frac{D + d}{2}\pi\right)$;

n being the number of rings in each flake.

For circular tanks the length in each flake is

$$= n\,\pi\,\frac{D + d}{2}.$$



$$\text{Number of flakes in tank} = \frac{\text{depth of tank}}{\text{diameter of cable}} \times 1\cdot08.$$

In coiling from outside to inside, the bight has at the end of each flake to be brought back, thus reducing the room. This reduction may be found by laying the cable loosely across the bight, and let a equal the distance from the *cross* to the spot where cable touches the remainder,

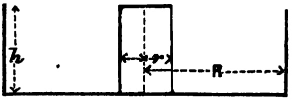
$$\text{then the reduction} = \frac{a}{\text{circ. of eye}}.$$

The total length of cable in any tank is, therefore,

$$L = \tfrac{1}{2} N (C + c) \times \frac{H}{d'} \times \begin{pmatrix} 1\cdot00 \\ \text{to} \\ 1\cdot15 \end{pmatrix} \times \left(1 - \frac{a}{c}\right).$$

Where L = total length.
N = number of rings in a flake.
C = circumference of tank.
c = circumference of eye.
H = depth of tank.
d' = diameter of cable.
1·00 = coefficient for circular tanks.
1·15 = coefficient for oval tanks.
a = crossing of cable. (*Hockin.*)

To find the capacity of a Circular Tank.



Let r = radius of the eye.
R = radius of the tank.
d = diameter of the cable.
n = number of coils in one flake.

Then

$$n = \frac{R - r}{d}. \qquad (1.)$$

The **length of the first coil** is

$$2\pi\left(r + \frac{d}{2}\right)$$

and **the length of the** *n*th coil is

$$2\pi\left\{r + \frac{d}{2} + (n - 1)\,d\right\}$$

Therefore, summing this arithmetic series, of which the first and last terms are given

$$\Sigma_n = \left\{2\pi\,(2\,r + n\,d)\right\}\frac{n}{2}$$

by substituting for n its value (1.)

$$\textit{length of one flake} = \frac{\pi}{d}(R^2 - r^2) \qquad (2.)$$

Let h be the height of tank or coil, then

$$\textbf{Total length of cable} = \frac{\pi h}{d^2}(R^2 - r^2). \qquad (3.)$$

Greatest Distances of visible Objects at Sea.

Let h = the height in feet of the object } above the
h' = the height in feet of the observer } water.
d = the distance of the object } from the point
d' = the distance of the observer } where the line joining both touches tangentially the water's surface (horizon).
$D = d + d'$ = the distance of the observer from the object.

$$\left.\begin{aligned} d &= 1{\cdot}31\sqrt{h} \\ d' &= 1{\cdot}31\sqrt{h'} \\ D &= 1{\cdot}31\left(\sqrt{h}+\sqrt{h'}\right) \end{aligned}\right\}\text{ in statute miles.}$$

$$\left.\begin{aligned} d &= 1{\cdot}23\sqrt{h} \\ d' &= 1{\cdot}23\sqrt{h'} \\ D &= 1{\cdot}23\left(\sqrt{h}+\sqrt{h'}\right) \end{aligned}\right\}\text{ in nautical miles.}$$

The Admiralty standard height, h', of the observer is = 10 feet.

Example.—The lantern of the Eddystone lighthouse is 72 *feet* ($= h$) *above the sea-level. An observer on the deck of a ship,* 16 *feet* ($= h'$) *above the water would just see the light at a distance*

$D = 1{\cdot}23\ (\sqrt{h} + \sqrt{h_{,}}) = 1{\cdot}23\ (\sqrt{72} + \sqrt{16}) = 15{\cdot}3$ *knots from the lighthouse.*

The distance in knots of a visible object at the sea-level is approximately equal to the square root of the height of the observer, in feet.

Distance of the Visible Horizon.

The distances are in knots, the heights in feet.

Height of Observer.	Distance of Horizon.	Height of Observer.	Distance of Horizon.	Height of Observer.	Distance of Horizon.	Height of Observer.	Distance of Horizon.
Feet.	Knots.	Feet.	Knots.	Feet.	Knots.	Feet.	Knots.
1	1·06	30	5·82	59	8·17	800	30·08
2	1·50	31	5·92	60	8·24	900	31·90
3	1·84	32	6·01	65	8·58	1000	33·63
4	2·13	33	6·11	70	8·89	1100	35·27
5	2·38	34	6·20	75	9·21	1200	36·84
6	2·60	35	6·29	80	9·51	1300	38·34
7	2·81	36	6·38	85	9·80	1400	39·79
8	3·01	37	6·47	90	10·09	1500	41·19
9	3·19	38	6·56	95	10·36	1600	42·54
10	3·36	39	6·64	100	10·63	1700	43·85
11	3·53	40	6·73	110	11·15	1800	45·12
12	3·68	41	6·81	120	11·65	1900	46·35
13	3·83	42	6·89	130	12·12	2000	47·56
14	3·98	43	6·97	140	12·58	2100	48·73
15	4·12	44	7·05	150	13·03	2200	49·88
16	4·25	45	7·13	160	13·45	2300	51·00
17	4·38	46	7·21	170	13·87	2400	52·10
18	4·51	47	7·29	180	14·27	2500	53·17
19	4·53	48	7·37	190	14·66	2600	54·22
20	4·78	49	7·44	200	15·04	2700	55·25
21	4·87	50	7·52	250	16·81	2800	56·77
22	4·99	51	7·59	300	18·42	2900	57·27
23	5·10	52	7·67	350	19·90	3000	58·25
24	5·21	53	7·74	400	21·27	3250	60·62
25	5·32	54	7·81	450	22·66	3500	62·91
26	5·42	55	7·89	500	23·78	3750	65·12
27	5·52	56	7·96	550	24·94	4000	67·26
28	5·62	57	8·03	600	26·05	4500	71·34
29	5·72	58	8·10	700	28·14	5000	75·20

Distance from Shore.—*Measurement by Sound.*—It sometimes happens that the distance of the ship from shore is required to be known, and a measurement by sound may be resorted to. For this purpose a gun is fired, and the interval between the flash and the sound noted.

Let D = distance in knots;
T = temperature of air in deg. Centigrade;
S = interval in seconds.

then

$$D = 0{\cdot}179\, S \sqrt{1 + 0{\cdot}00374\, T}.$$

Example.—A ship fired a cannon, and the sound was heard $6\frac{1}{2}$ seconds after the flash was seen. The temperature of the air was 15° C. Required the distance (D) of the ship.

$$D = 0{\cdot}179 \times 6\tfrac{1}{2}\sqrt{1 + 0{\cdot}00374 \times 15} = 1{\cdot}2 \text{ knots.}$$

Descriptions of Sound.

	Audible at a distance of
Powerful human voice . . .	200 yards
Drum	2 knots
Horn	3 ,,
Musket	3 ,,
Cannon	10 to 90 ,,

Velocity of Sound.

Velocity of sound in air		=	1,142 ft. per second.
Ditto ,,	water	=	4,900 ,,
Ditto ,,	iron	=	17,500 ,,
Ditto ,,	copper	=	10,378 ,,
Ditto ,,	wood	=	12,000 ,,
			to 16,000 ,,

To find the distance from ship to shore by the sextant.—Let an assistant on shore set up two staves so as to form a base line at right angles to the position of the vessel, and signal their distance apart; the observer on board ship measures the angle subtended in degrees and minutes, and multiplies the distance by the constant in the subjoined table.

Example.—The distance between two staves on shore is 420 yards, and the angle measured from the ship is 26° 30′, the distance of the nearer staff is 2·01 × 420 = 844 yards.

To find the distance from ship to shore by the sextant.

Degs.	DISTANCES.					
	0′	10′	20′	30	40′	50′
5	11·43	11·06	10·71	10·39	10·08	9·79
6	9·51	9·26	9·01	8·78	8·56	8·34
7	8·14	7·95	7·77	7·60	7·43	7·27
8	7·12	6·97	6·83	6·69	6·56	6·43
9	6·31	6·20	6·08	5·98	5·87	5·77
10	5·67	5·58	5·48	5·40	5·31	5·23
11	5·14	5·07	4·99	4·92	4·84	4·77
12	4·70	4·64	4·57	4·51	4·45	4·39
13	4·33	4·27	4·22	4·17	4·11	4·06
14	4·01	3·96	3·91	3·87	3·82	3·78
15	3·73	3·69	3·65	3·61	3·57	3·53
16	3·49	3·45	3·41	3·38	3·34	3·31
17	3·27	3·24	3·20	3·17	3·14	3·11
18	3·08	3·05	3·02	2·99	2·96	2·93
19	2·90	2·88	2·85	2·82	2·80	2·77
20	2·75	2·72	2·70	2·67	2·65	2·63
21	2·61	2·58	2·56	2·54	2·52	2·50
22	2·48	2·45	2·43	2·41	2·39	2·38
23	2·36	2·34	2·32	2·30	2·28	2·26
24	2·25	2·23	2·21	2·19	2·18	2·16
25	2·14	2·13	2·11	2·10	2·08	2·07
26	2·05	2·04	2·02	2·01	1·99	1·98
27	1·96	1·95	1·93	1·92	1·91	1·89
28	1·88	1·87	1·85	1·84	1·83	1·82
29	1.80	1·79	1·78	1·77	1·76	1·74
30	1·73	1·72	1·71	1·70	1·69	1·68
31	1·66	1·65	1·64	1·63	1·62	1·61
32	1·60	1·59	1·58	1·57	1·56	1·55
33	1·54	1·53	1·52	1·51	1·50	1·49
34	1·48	1·47	1·46	1·46	1·45	1·44
35	1·43	1·42	1·41	1·40	1·39	1·38
36	1·38	1·37	1·36	1·35	1·34	1·34
37	1·33	1·32	1·31	1·30	1·30	1·29
38	1·28	1·27	1·26	1·26	1·25	1·24
39	1·23	1·23	1·22	1·21	1·21	1·20
40	1·19	1·18	1·18	1·17	1·16	1·16

SOUNDINGS.

To reduce Soundings to Low Water.

Letters denote—

T = Interval in hours between low and high water.

t = Interval in hours from low water to the time when the sounding is taken.

H = Vertical rise of tide, in feet, from low to high water.

h = Height, in feet, to be subtracted from the sounding taken at the time, t,

$$h = \frac{H}{2}\left\{1 \mp \cos\left(180^\circ \frac{t}{T}\right)\right\}$$

$$-\cos\left(180 \frac{t}{T}\right) \text{ when } t < \tfrac{1}{2} T;$$

$$+\cos\left(180 \frac{t}{T}\right)^\circ \text{ when } t > \tfrac{1}{2} T.$$

Example.—High water at 10h. 15m. p.m.
Low water at 3h. 45m. ,,
Interval (T) = 6h. 30m. ,, = 6·5 hours.
The sounding taken at 5h. 30m. ,, was 16 feet 6 inches.
Interval (t) = 1h. 45m. = 1·75 hours.
Vertical rise H = 9·75 feet,
Required the reduction and true sounding at low water.

$$\left(180 \frac{t}{T}\right) = \frac{180 \times 1{\cdot}75}{6{\cdot}5} = 48^\circ\ 30',$$

$$\cos 48^\circ\ 30' = 0{\cdot}66262.$$

$$h = \frac{9{\cdot}75}{2}(1 - 0{\cdot}66262) = 1{\cdot}6447 \text{ feet.}$$

Sounding taken at 5h. 30m. was	16·5	,,
(subtract) h =	1·6447	,,
True sounding at low water	14·8553	,,

DEEP SEA SOUNDING.—(Average Velocity of Descent of Lead Weight in Feet per Second.)

Weight in lbs.	115	96	96	96	94	70	68	68	64	64	64	60	40	40	35	32	32	32	32
Depth in Fathoms.	Cod Line.	Deep Sea Line.	French Silk Line.	Tapered Whale Line.	Cod Line.	Two-yarn Spun-yarn.	Mixed Line.	Mixed Line.	Small Line.	Small Line.	Small Line Waxed.	Mackerel Line.	Mackerel Line.	Mackerel Line.	French Silk Line.	Small Line.	Small Line Waxed.	Small Line.	Small Line. Waxed.
	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
0 to 200	. .	8·935	11·510	5·455	..	15·789	7·018	. .	9·161	8·510	..	8·759	7·500	10·000	10·701	..	..	8·219	9·678
200 „ 400	7·843	5·744	8·335	4·839	7·186	6·250	5·761	6·486	5·941	5·941	6·976	5·487	4·669	4·255	8·193	5·000	5·660	5·286	7·186
400 „ 600	6·349	4·458	6·825	4·396	5·530	4·899	4·343	4·572	4·919	5·000	5·741	4·444	3·738	3·315	5·774	3·947	4·743	4·167	5·825
600 „ 800	5·480	3·972	5·816	4·511	4·563	4·396	3·825	3·395	4·225	4·301	5·042	3·862	3·208	3·200	4·646	3·459	4·068	3·593	4·979
800 „ 1,000	4·669	3·624	5·271	4·380	4·167	3·921	3·433	3·380	3·834	3·810	4·460	3·456	2·905	..	3·957	3·023	3·715	3·217	4·724
1,000 „ 1,200	4·348	3·436	5·102	4·081	3·774	3·604	3·445	2·993	3·390	3·438	4·040	3·033	2·740	..	3·562	2·752	3·400	2·885	4·428
1,200 „ 1,400	4·081	3·319	4·500	4·301	3·571	3·351	2·830	2·844	3·191	3·234	3·858	2·857	2·637	..	3·450	2·598	3·175	2·728	4·255
1,400 „ 1,600	3·738	3·200	4·380	4·255	3·270	3·333	..	..	3·023	3·061	3·637	2·728	2·542	..	3·160	2·400	3·015	2·510	4·210
1,600 „ 1,800	3·519	3·141	4·212	4·316	3·069	3·101	..	..	2·857	2·817	3·560	2·637	2·526	..	2·910	2·281	2·824	2·312	3·360
1,800 „ 2,000	..	3·052	2·925	4·167	3·037	2·927	..	..	2·654	2·690	3·288	2·489	2·400	..	2·840	2·182	2·734	2·210	3·762
2,000 „ 2,200	..	2·945	..	..	2·927	2·791	..	..	2·494	2·563	3·175	..	..	..	2·469	2·087	2·684	2·090	3·370
2,200 „ 2,400	..	..	..	..	2·784	2·830	..	..	2·424	2·500	3·015	..	..	..	2·405	1·977	2·581	1·990	3·175

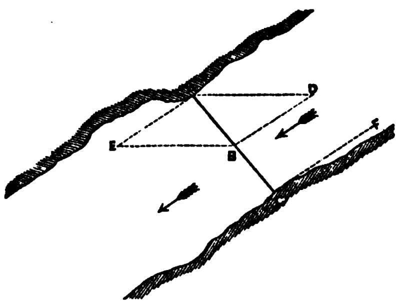
SOUNDING LINES.

Line.	Number of Threads.	Weight per 100 Fathoms.		Circumference.	Breaking Strain.	
					Dry.	Wet.*
		lbs.	oz.	Inches.	lbs.	lbs.
Deep sea (Portsmouth)	27	18	9	1·0	1,760	1,559
Deep sea, hawser laid (Devonport)	27	24	6	1·066	1,176	952
Medium (Portsmouth)	18	12	8	0·8	1,402	1,211
Ordinary deep sea, cable laid (Devonport Dockyard) . .	18	23	14	1·065	815	630
Cod (Portsmouth)	9	6	4	0·55	740	777
Cod (Devonport)	9	7	0	0·565	494	469
Ordinary cod (Devonport) . . .	6	6	2	0·540	254	252

* After soaking 24 hours.

Steering Across Currents.

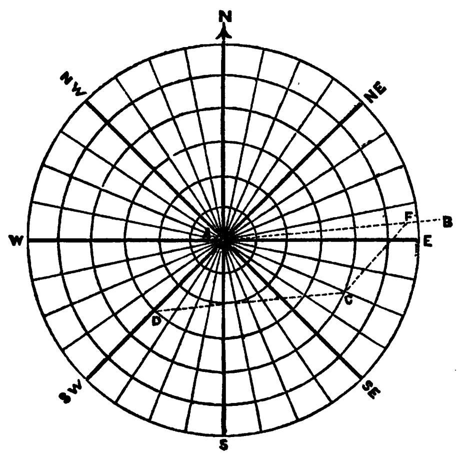
If it be required to lay a cable from two given points, A and C, between which a current runs (in the



direction shown by the arrows) with a known velocity, the direction in which the ship must be steered in order to pay out the cable with the least possible loss is found by constructing the parallelogram of forces, A B D E. Let

the A E line, in the direction of the current, represent its velocity in knots per hour; let A C be the cable in knots; and A B, measured off from the point A, be the rate at which it is determined to pay it out per hour. We then construct the parallelogram, A B D E, in which A D gives the direction and required rate of the ship.

A convenient diagram card is in use by the naval



officers for this purpose. Around the centre of a compass card are described six or more concentric and equidistant circles, each representing a knot of distance. When it is required to find the rate and direction of a ship across a current, it is done by making the centre the starting-point, and laying off from it the direction and velocity of the current, and the resultant direction, and velocity of the ship, with which a parallelogram is

constructed, the new side, starting from the centre, giving at once the direction and rate.

Example.—A current is setting towards the S.W., at the rate of 3 knots an hour, whilst it is required to make good an E.S.E. course, at the rate of 4 knots an hour.

Where the S.W. line intersects the 3-knot circle, we mark off the point D; and where the E.S.E. line intersects the 4-knot circle, the point C. Between these two points we draw the straight line, C D, and parallel to this, and to the line joining D with the centre A, we draw the remaining lines A B and C F, which complete the parallelogram.

The course in which the ship is to steer is given by the line A B, in this case E $\frac{1}{2}$ N; and the rate at which she must go through the water by the distance of F from the centre, in this case $5\frac{2}{3}$ knots.

SEA WATER.

The specific gravity of sea water is ordinarily 1·028.

One cubic foot weighs 64·24 lbs.

One cubic foot of distilled water weighs 62·5 lbs.

The pressure of the ocean is equal to 2·676 lbs. per square inch per fathom, or one ton one cwt. per statute mile of depth. Hence, in the Atlantic, where the depth is about two miles, the pressure will be two tons two cwt. for each square inch of surface.

The temperature of the ocean below a depth of 1200

fathoms is believed to be about 4° Centigrade, that is to say, the temperature of water of maximum density.

Force of the Waves.—From experiments made by Mr. A. Stevenson, at the Skerryvore Lighthouse, on the west coast of Scotland, exposed to the whole fury of the Atlantic, it appears that the average pressure of the waves during the summer is equal to 611 lbs. weight on a square foot of surface, while in winter it was 2086 lbs., or three times as much; during the storm on the 9th of March, 1845, it amounted to 6013 lbs.

The effect of a gale descends to a comparatively small distance below the surface. The sea is probably tranquil at the depth of 200 or 300 yards.

MEMORANDA CONNECTED WITH WATER.

1 cubic foot of water	= 62·5 lbs.	= 1000 oz. at 60° F.	
1 cubic inch . .	= ·036 lbs.		
1 gallon	= 10 lbs.		
or	= 0·16 cube feet.		
1 cube foot of water	= 6·2355 gallons.		
or, approximately	= 6¼ „		
1 cwt. of water. .	= 1·8 cube ft.	= 11·2 gals.	
1 ton of water . .	= 35·9 cube ft.	= 224 „	

Absorption of Water by Insulators.

	In Fresh Water.		In Salt Water.	
Raw india-rubber . . .	25	per cent.	3	per cent.
Unvulcanized block india-rubber	23	„	3·8	„
India-rubber and mica .	19	„	3·9	„
Vulcanized india-rubber .	10·14	„	2·9	„
Gutta-percha	1·5	„	1·0	„

Determination of the Height and Velocity of the Waves off the Cape of Good Hope, 1847. By Commander Dayman, R.N.

Date.	No. of Obser-vation.	Speed of Ship.	Height of Wave.	Length of Wave.	Speed of Sea per Hour.	Remarks.
1847		Knot.	Feet.	Fath.	Knot.	
Ap. 21	—	7·2	22	55	27·0	Before the wind, with a heavy following sea.
,, 23	8	6·0	20	43	24·5	
,, 24	6	6·0	20	50	24·0	
,, 25	9	5·0	—	37	22·1	
,, 26	—	6·0	—	33	22·1	
May 2	6	7·0	22	57	26·2	Sea irregular and on port quarter.
,, 3	7	7·8	17	35	22·0	
Mean	..	..	20	44	24·0	

To find the length of cable required to join two given points.—The rough way is to draw a straight line between the two places upon the chart, and measure off its length with that of a degree (= 60 knots) taken from the margin at about the latitude of the middle. In high latitudes when the distances are great, however, this method will give very fallacious results, and we must have recourse to spherical trigonometry.

Let the lower latitude be l, and longitude L, the higher latitude be l', and its longitude L′. The shortest distance, d, in degrees of the great circle between these two places is found by the equation

$$\cos d = \frac{\sin l' . \cos n}{\cos m},$$

in which

$$\tan m = \cot l' \cos (\mathrm{L} - \mathrm{L}'),$$
$$n = 90^\circ \pm l - m.$$

In the value of n, the latitude l is $+$ when the places

are on opposite sides of the equator, and – when both are on the same side of it.

Example.—Required the shortest distance between the Lizard in latitude 49° 57′ *N., longitude* 5° 14′ *W., and the west end of the island of Madeira in latitude* 32° 30′ *N., longitude* 17° 26′ *W.*

According to the above $(L - L') = 17° 26' - 5° 14' = 12° 12'$

$$\tan m = \cot 49° 57' \times \cos 12° 12'$$
$$= 0{\cdot}8406 \times 0{\cdot}9775 = 0{\cdot}817 = \tan 39° 14'$$
$$n = 90° - 32° 30' - 39° 24' = 18° 6'$$

and

$$\cos d = \frac{\sin 49° 57' \times \cos 18° 6'}{\cos 39° 24'} = \frac{0{\cdot}7655 \times 0{\cdot}9505}{0{\cdot}7727} =$$
$$0{\cdot}9412 = \cos 19° 45'$$

The shortest distance is therefore

$$19° \times 60 + 45 = 1185 \text{ knots.}$$

In specifying deep-sea cables it is safe to provide 20 to 25 per cent. more than the direct distance; and for shallow-sea cables 5 to 7½ per cent.

To find the course of the Ship.—Adopting the designations given above, the course from the lower latitude to the higher is obtained by

$$\sin C = \frac{\sin (L - L')}{\sin d} \cos l'$$

and that from the higher latitude to the lower, by

$$\sin C' = \frac{\sin L - L'}{\sin d} \cos l.$$

Example.—Let us take again our supposed line. We have the course from Madeira given by

$$\sin C = \frac{\sin 12° 12'}{\sin 19° 45'} \cos 49° 57' = \sin 23° 44'$$

The ship would therefore start from Madeira North (23° 44′) East.

From Lizard the course is given by

$$\sin C' = \frac{\sin 12° 12}{\sin 19° 45} \cos 32° 30' = \sin 31° 50',$$

the ship must therefore approach the English station in a course South (31° $30'$) West.

The course of a ship is usually given in *points* of the compass east and west of true north and south. A point is equal to 11° $15'$ of arc.

To find the difference of time between two places.—Each 15° difference of longitude represents one hour difference of time.

Therefore divide the difference of the longitudes of two given places by 15, and the quotient gives the difference in time.

The longitude of Greenwich is 0° $0'$, and that of New York 74° $7'$ W. The difference in time between them is therefore

$$\frac{74^\circ\ 7'}{15} = 4 \text{ h. } 56\tfrac{1}{2} \text{ min.}$$

THE LOG-LINE AND HALF-MINUTE GLASS.

The principle of the log-line is this: The length of each knot upon the line bears the same proportion to the length of a sea-mile as half a minute does to an hour. Therefore the length of each knot of the line is, or should be, the $\frac{1}{120}$ part of a sea-mile. The length of a sea-mile is generally taken at 6120 feet, so that the length of a knot on the line is 51 feet. In submarine telegraph work, however, a sea-mile is assumed to be 6087 feet only (or 2029 yards), and as the telegraph cable is measured in this unit of length, the speed of the ship should be measured to it also, or an error will arise in the amount of

slack paid out. The length of a knot of the log-line of a cable-ship must therefore be $\frac{6087}{120} = 50\cdot723$ feet for the half-minute glass.

A correction for the glass is sometimes necessary, the length of the knot on the line being increased or decreased in the same ratio as the glass takes a longer or shorter time than 30 seconds to run out. Thus, if the glass run out in 28 seconds, the knot lengths would be only $50\cdot723 \times \frac{28}{30} = 47\cdot34$ feet.

TABLE for reducing weights of cables, *per foot*, to weight, *per knot*, of 2029 yards = 6087 feet.—(*Forde.*)

Weight of 1 foot Specimen.	EQUIVALENT OF KNOT.	
	Lbs.	Cwt.
Pounds.		
1	6·087	54·348
2	12·174	108 696
3	18·261	163·045
4	24·348	217·393
5	30·345	271·741
6	36·522	326·089
7	42·609	380·437
8	48·696	434·786
9	54·783	489·134
10	60·870	543·482
Ounces.		
1	380	3·307
2	760	6·794
3	1141	10·190
4	1522	13·587
5	1902	16·984
6	2282	20·381
7	2663	23·777
8	3043	27·174
9	3423	30·571
10	3804	33·968
11	4184	27·364
12	4565	40·761
13	4945	44·158
14	5326	47·555
15	5706	50·951
16	6087	54·348

Weight of 1 foot Specimen.	EQUIVALENT OF KNOT.	
	Lbs.	Cwt.
Grains.		
1	0·8696	·0078
2	1·7391	·0155
3	2·6087	·0233
4	3·4783	·0310
5	4·3479	·0388
6	5·2174	·0466
7	6·0870	·0543
8	6·9566	·0621
9	7·8261	·0699
10	8·6957	·0767
20	17·3914	·1553
30	26·0871	·2329
40	34·7828	·3106
50	43·4786	·2882
60	52·1743	·4650
70	60·8700	·5435
80	69·5657	·6211
90	78·2614	·6988
100	86·9571	·7665
200	173·9142	1·5528
300	260·8713	2·3292
400	347·8284	3·1055

To find the weight, per knot, of a given cable by the above Table :—*Weigh a length of one foot of the cable and add together the equivalents for lbs., oz., and grains.*

Example.—A foot length of cable weighed 2 lbs., 5 oz., and 74 grains. Its weight, per knot, is therefore obtained as follows :

2 lbs.	. .	108·696 cwt.
5 oz.	. .	16·984 ,,
70 grs.	. . .	·544 ,,
4 ,,	. . .	·031 ,,

Total = 126·255 cwt., per knot.

Extra material required by twisting helically.

L = length of finished cable or strand in yards.

l = length of one wire required to lap it helically in yards.

D = outside diameter in inches.

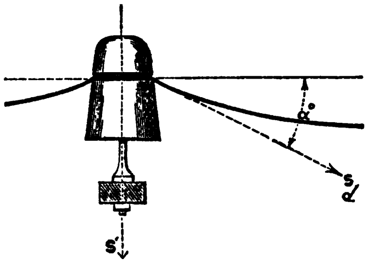
δ = diameter of helical wire in inches.

h = lay in inches.

$$l = L.\frac{\sqrt{h^2 + 9{\cdot}8696\,(D - \delta)^2}}{h} \text{ in yards.}$$

OVERLAND LINES.

Strains of suspended wires.—The suspended wire may be regarded as a parabola. It is usually stretched



so as to allow, in a distance, l = 240 feet between the supporting insulators, a sag, h = $1\frac{1}{2}$ feet in mild weather, which is on the average equivalent to

$$h = 0{\cdot}006\,l.$$

The length L of the suspended wire is

$$L = l\left(1 + \frac{8}{3}.\frac{h^2}{l^2}\right) \text{feet.}$$

The vertical strain S_r or weight upon each insulator is

$$S_r = \frac{L\,d^2\pi\,\sigma}{4}\ \text{lbs.}$$

in which σ is 3·38 lbs., the weight of a foot length of inch square iron bar, and d the diameter of the wire in inches. Therefore

$$\textbf{Vertical strain} = 2{\cdot}65\ L\,d^2.$$

The greatest strain, S_d, at the points of suspension, in the direction of the wire, is

$$S_d = \frac{S_r}{2} \cdot \frac{1}{\sin a} = \frac{L\,d^2\pi\,\sigma}{8} \cdot \frac{\sqrt{l^2 + 16\,h^2}}{4\,h}.$$

As h is invariably very small in comparison with l, the value h^2 may be altogether neglected, and L may be put equal to l, so that giving the numerical value to the constants, the above equation becomes

$$\textbf{Greatest strain} = 0{,}33\,\frac{l^2\,d^2}{h}\ \text{lbs., or}\ \frac{l^2\,w}{374\,h}\ \text{lbs.,}$$

where w is the weight in cwts. of one statute mile.

Numerical Example.—Posts are 240 feet apart; wire No. 8, B. W. G. ($d = 0{\cdot}165''$); sag in middle, 1·5 feet;

$$\textbf{Vertical strain} = 2{\cdot}65 \times 240 \times {\cdot}165^2 = 17{\cdot}3\ \text{lbs.}$$

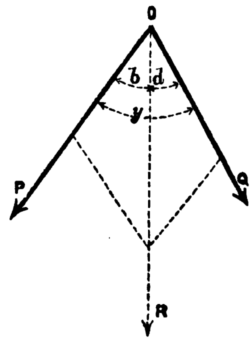
$$\textbf{Greatest strain} = 0{,}33 \times \frac{240^2 \times 0{\cdot}165^2}{1{\cdot}5} = 345\ \text{lbs.}$$

The Composition of Forces for finding the positions of stays and struts for telegraph posts.

Two wires, P and Q, pull in different directions upon the post O, have a resultant, R, expressed by the diagonal

of the parallelogram, by which they might be replaced. The forces stand in the relation

$$P : Q : R = \sin d : \sin b : \sin y :$$



The resultant is

$$R = \sqrt{P^2 + Q^2 + 2\,PQ \,.\, \cos y}.$$

When y is a right angle,

$$P = R \cos b \qquad Q = R \cos a$$

$$R = \sqrt{P^2 + Q^2}.$$

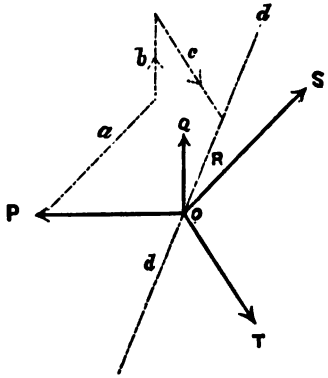
When d is a right angle,

$$P = \frac{R}{\cos b} \qquad Q = R \tan b$$

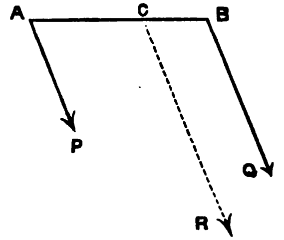
$$R = \sqrt{P^2 - Q^2}.$$

The forces of *several wires*, P, Q, S, T, pulling in different directions, in the same plane, upon the post O, may be compounded graphically, which is exact enough for all practical purposes, by describing from the point O a polygonal figure O P, *a b c d* (shown in dotted lines), whose sides are equal to, and parallel to, the directions

of the given forces. The side, R, completing the figure, gives the value of the resultant, and its direction in the line *d d*, in which a stay or strut must be placed.



Two parallel wires of different lengths or tensions, P and Q, acting upon the rigid arm, A B, have a resultant



which is equal to their sum, and act in the direction

of the greater. Its position is determined by the proportions

$$AC : AB = Q : R$$

and

$$BC : AB = P : R.$$

The arm should therefore be fastened to the post at the point C.

Opposite forces acting parallel and equally upon different points of any system tend to impart to it a rotary motion.

TABLE showing the Strain corresponding to the Sag or Dip of a Wire suspended at both ends.—(*Culley.*)

Sag in inches.	No. 8 wire, ordinary, 88 yards span.	No. 8 wire, 110 yards span.	No. 11 wire, homogeneous, 110 yards span.	No. 11 wire, homogeneous, 110 yards span.
	lbs.	lbs.	lbs.	lbs.
24	313	429	266	224
23	326	448	280	235
22	340	467	291	246
21	359	486	302	257
20	377	504	313	268
19	397	532	324	280
18	418	560	336	294
17	448	588	355	308
16	477	616	374	322
15	510		392	336
14	543		420	355
13	583		448	374
12	624		476	392
11	690		504	420
10	756			448
9	841			476
8	926			504
7	1018			

Approximate Cubical Contents of round Telegraph Poles.

Length.	MEAN DIAMETERS IN INCHES.																
	5	5¼	5½	5¾	6	6¼	6½	6¾	7	7¼	7½	7¾	8	8¼	8½	8¾	9
Feet. 18	2·45	2·70	2·96	3·24	3·53	3·83	4·14	4·47	4·81	5·16	5·52	5·89	6·28	6·68	7·09	7·51	7·95
20	2·72	3·00	3·29	3·60	3·92	4·25	4·60	4·97	5·34	5·73	6·13	6·55	6·98	7·42	7·88	8·35	8·83
22	2·99	3·30	3·62	3·96	4·31	4·68	5·07	5·46	5·87	6·30	6·74	7·20	7·67	8·16	8·66	9·18	9·71
24	3·27	3·60	3·95	4·32	4·71	5·11	5·53	5·96	6·41	6·88	7·36	7·86	8·37	8·90	9·45	10·02	10·60
26	3·54	3·90	4·28	4·68	5·11	5·53	5·99	6·46	6·94	7·45	7·97	8·51	9·07	9·65	10·24	10·85	11·48
28	3·81	4·20	4.62	5·04	5·49	5·96	6·45	6·95	7·48	8·02	8·58	9·17	9·77	10·39	11·03	11·69	12·37
30	4·09	4·50	4·94	5·40	5·88	6·38	6·91	7·45	8·01	8·60	9·20	9·82	10·47	11·13	11·82	12·52	13·25
32	4·36	4·81	5·27	5·77	6·28	6·81	7·37	7·95	8·55	9·17	9·81	10·48	11·17	11·87	12·61	13·36	14·13
34	4·63	5·11	5·60	6·13	6·67	7·24	7·83	8·44	9·08	9·74	10·43	11·13	11·86	12·62	13·39	14·19	15·02
36	4·90	5·41	5·93	6·49	7·06	7·66	8·29	8·94	9·62	10·32	11·04	11·79	12·56	13·36	14·18	15·03	15·90
38	5·18	5·71	6·26	6·85	7·46	8·09	8·75	9·44	10·15	10·89	11·65	12·44	13·26	14·10	14·97	15·86	26·78
40	5·45	6·01	6·59	7·21	7·85	8·52	9·21	9·94	10·69	11·46	12·27	13·10	13·96	14·84	15·76	16·70	17·67

Timber Measuring.

G = $\frac{1}{4}$th girt of tree at middle in feet.
g = $\frac{1}{4}$th girt of tree at one end in feet.
g' = $\frac{1}{4}$th girt of tree at the other end in feet.
L = Length of log in feet.
c = Cube contents of log in feet.

$$c = \mathrm{L}\left(\frac{\mathrm{G}+g+g'}{3}\right)^2.$$

Allowance is to be made for bark by deducting from each $\frac{1}{4}$th girt.

Measures in which the Lengths of Over-head Lines are expressed in Various Countries.

		Length in Eng. Yards.		English Miles.		Eng. Miles.	Miles, &c., of different Countries.
Arabia	Mile	2148	100 =	122·04	and	100 =	81·93
Austria	Mile	10126	do.	575·34	,,	do.	17·38
Bohemia	Mile	10137	do.	575·96	,,	do.	17·36
Brabant	League.	6076	do.	345·22	,,	do.	28 96
Burgundy	League.	6183	do.	351·66	,,	do.	28·46
China	Li	632	do.	35·91	,,	do.	278·48
Denmark	Mile	8244	do.	468·41	,,	do.	21 35
England	Mile	1760	do.	100·	,,	do.	100·
Flanders	League.	6864	do.	390·	,,	do.	25·64
France	Kilomètre	1093	do.	62 10	,,	do.	161·02
Hamburg	Mile	8244	do.	468·41	,,	do.	21·35
Hanover	Mile	11559	do.	656·76	,,	do.	15·22
Hesse	Mile	10547	do.	599·26	,,	do.	16·68
Holland	Mile	8101	do.	460 28	,,	do.	21·72
Hungary	Mile	9113	do.	517·78	,,	do.	19·31
Italy	Mile	2025	do.	115·05	,,	do.	86·91
Lithuania	Mile	9781	do.	555·73	,,	do.	18·00
Norway	Mile	12352	do.	701 83.	,,	do.	14·25
Oldenburg	Mile	10820	do.	614 77	,,	do.	16·26
Poland	Long Mile.	8101	do.	460·28	,,	do.	21·72
,,	Short Mile.	6075	do.	345·17	,,	do.	28 97
Portugal	League.	6760	do.	384·09	,,	do.	26·03
Prussia	Mile	8237	do.	480·68	,,	do.	21·37
Rome	Mile	1628	do.	92 50	,,	do.	108·11
Russia	Verst	1167	do.	66·30	,,	do.	150·81
Saxony	Mile	9905	do.	562 78	,,	do.	17·76
Silesia	Mile	7083	do.	402·44	,,	do.	24·84
Spain	Common Legua of 8000 Varas	7416	do.	421·36	,,	do.	23·73
,,	Legal Legua of 5000 Varas	4635	do.	563 35	,,	do.	37·97
Swabia	Mile	10126	do.	275·34	,,	do.	17·38
Sweden	Mile	11700	do	664·77	,,	do.	15·04
Switzerland	Mile	9153	do.	520·05	,,	do.	19·23
Turkey	Berri	1826	do.	103·75	,,	do.	96·38
Tuscany	Mile	1808	do.	102·72	,,	do.	97·34
Westphalia	Mile	12151	do.	690·39	,,	do.	14·48

Statistics of some Telegraph Systems.

Scudamore's Report.

	In Belgium.	In Switzerland.	In the United Kingdom.
(1865.) Miles of telegraphic line to every 100 square miles of territory. . . .	Miles. 17¾	Miles. 13$\frac{7}{10}$	Miles. 11$\frac{3}{10}$
Number of telegraphic offices to every 100,000 persons .	Offices. 6⅓	Offices. 9$\frac{9}{10}$	Offices. 5$\frac{6}{10}$
Increase per cent. in 1866 over 1865 :	Per cent.	Per cent.	Per cent.
Miles of line .	9	3¾	3¼
Miles of wire .	15	10	4
Telegraph offices	16	12½	7
Instruments . .	15½	13½	11
Proportion of Inland Telegrams to Inland Letters . . 1860	Telegrams Letters 1 to 218	Telegrams Letters 1 to 84	Telegrams Letters 1 to 296
Ditto Ditto 1861	1 " 195	1 " 87	1 " 273
Ditto Ditto 1862	1 " 187	1 " 80	1 " 221
Ditto Ditto 1863	1 " 114	1 " 74	1 " 197
Ditto Ditto 1864	1 " 88	1 " 70	1 " 169
Ditto Ditto 1865	1 " 73	1 " 69	1 " 151
Ditto Ditto 1866	1 " 37	1 " 69	1 " 121
Cost per mile of line of working and maintaining Telegraph. . . 1865	£ s. d. 4 18 4	£ s. d. 5 5 0	£ s. d. 4 10 0
Ditto Ditto 1866	5 7 6	5 3 2	4 10 2
Number of messages per mile of line 1862	Messages per Mile. 97	Messages per Mile. 128	Messages per Mile. 47
Ditto Ditto 1865	124	159	61
Ditto Ditto 1866	181	163	78

COMPARATIVE TABLE of the Degrees of the three Thermometrical Scales.

To convert the Degrees of Fahrenheit into those of Reaumur and Celsius (the Centigrade); and conversely.

Fahrenheit into Reaumur $\frac{F - 32}{9} \times 4 = R.$

Fahrenheit into Celsius $\frac{F - 32}{9} \times 5 = C.$

Reaumur into Fahrenheit $\frac{R \times 9}{4} + 32 = F.$

Celsius into Fahrenheit $\frac{C \times 9}{5} + 32 = F.$

TABLE of Comparison of different Thermometers.

Fah.	Reau.	Cent.	Fah.	Reau.	Cent.	Fah.	Reau.	Cent.	Fah.	Reau.	Cent.
212	80·0	100·0	153	53·7	67·2	94	27·5	34·4	35	1·3	1·6
211	79·5	99·4	152	53·3	66·6	93	27·1	33·8	34	0·8	1·1
210	79·1	98·8	151	52·8	66·1	92	26·6	33·3	33	0·4	0·5
209	78·6	98·3	150	52·4	65·5	91	26·2	32·7	32	0·0	0·0
208	78·2	97·7	149	52·0	65·0	90	25·7	32·2	31	— 0·4	— 0·5
207	77·7	97·2	148	51·5	64·4	89	25·3	31·6	30	— 0·8	— 1·1
206	77·3	96·6	147	51·1	63·8	88	24·8	31·1	29	— 1·3	— 1·6
205	76·8	96·1	146	50·6	63·3	87	24·4	30·5	28	— 1·7	— 2·2
204	76·4	95·5	145	50·2	62·7	86	24·0	30·0	27	— 2·2	— 2·7
203	76·0	95·0	144	49·7	62·2	85	23·5	29·4	26	— 2·6	— 3·3
202	75·5	94·4	143	49·3	61·6	84	23·1	28·8	25	— 3·1	— 3·8
201	75·1	93·8	142	48·8	61·1	83	22·6	28·3	24	— 3·5	— 4·4
200	74·6	93·3	141	48·4	60·5	82	22·2	27·7	23	— 4·0	— 5·0
199	74·2	92·7	140	48·0	60·0	81	21·7	27·2	22	— 4·4	— 5·5
198	73·7	92·2	139	47·5	59·4	80	21·3	26·6	21	— 4·8	— 6·1
197	73·3	91·6	138	47·1	58·8	79	20·8	26·1	20	— 5·3	— 6·6
196	72·8	91·1	137	46·6	58·3	78	20·4	25·5	19	— 5·7	— 7·2
195	72·4	90·5	136	46·2	57·7	77	20·0	25·0	18	— 6·2	— 7·7
194	72·0	90·0	135	45·7	57·2	76	19·5	24·4	17	— 6·6	— 8·3
193	71·5	89·4	134	45·3	56·6	75	19·1	23·8	16	— 7·1	— 8·8
192	71·1	88·8	133	44·8	56·1	74	18·6	23·3	15	— 7·5	— 9·5
191	70·6	88·3	132	44·4	55·5	73	18·2	22·7	14	— 8·0	—10·0
190	70·2	87·7	131	44·0	55·0	72	17·7	22·2	13	— 8·4	—10·5
189	69·7	87·2	130	43·5	54·4	71	17·3	21·6	12	— 8·8	—11·1
188	69·3	86·6	129	43·1	53·8	70	16·8	21·1	11	— 9·3	—11·6
187	68·8	86·1	128	42·6	53·3	69	16·4	20·5	10	— 9·7	—12·2
186	68·4	85·5	127	42·2	52·7	68	16·0	20·0	9	—10·2	—12·7
185	68·0	85·0	126	41·7	52·2	67	15·5	19·4	8	—10·6	—13·3
184	67·5	84·4	125	41·3	51·6	66	15·1	18·8	7	—11·1	—13·8
183	67·1	83·8	124	40·8	51·1	65	14·6	18·3	6	—11·5	—14·4
182	66·6	83·3	123	40·4	50·5	64	14·2	17·7	5	—12·0	—15·0
181	66·2	82·7	122	40·0	50·0	63	13·7	17·2	4	—12·4	—15·5
180	65·7	82·2	121	39·5	49·4	62	13·3	16·6	3	—12·8	—16·1
179	65·3	81·6	120	39·1	48·8	61	12·8	16·1	2	—13·3	—16·6
178	64·8	81·1	119	38·6	48·3	60	12·4	15·5	1	—13·7	—17·2
177	64·4	80·5	118	38·2	47·7	59	12·0	15·0	0	—14·2	—17·7
176	64·0	80·0	117	37·7	47·2	58	11·5	14·4	— 1	—14·6	—18·3
175	63·5	79·4	116	37·3	46·6	57	11·1	13·8	— 2	—15·1	—18·8
174	63·1	78·8	115	36·8	46·1	56	10·6	13·3	— 3	—15·5	—19·4
173	62·6	78·3	114	36·4	45·5	55	10·2	12·7	— 4	—16·0	—20·0
172	62·2	77·7	113	36·0	45·0	54	9·7	12·2	— 5	—16·4	—20·5
171	61·7	77·2	112	35·5	44·4	53	9·3	11·6	— 6	—16·8	—21·1
170	61·3	76·6	111	35·1	43·8	52	8·8	11·1	— 7	—17·3	—21·6
169	60·8	76·1	110	34·6	43·3	51	8·4	10·5	— 8	—17·7	—22·2
168	60·4	75·5	109	34·2	42·7	50	8·0	10·0	— 9	—18·2	—22·7
167	60·0	75·0	108	33·7	42·2	49	7·5	9·4	—10	—18·6	—23·3
166	59·5	74·4	107	33·3	41·6	48	7·1	8·8	—11	—19·1	—23·8
165	59·1	73·8	106	32·8	41·1	47	6·6	8·3	—12	—19·5	—24·4
164	58·6	73·3	105	32·4	40·5	46	6·2	7·7	—13	—20·0	—25·0
163	58·2	72·7	104	32·0	40·0	45	5·7	7·2	—14	—20·4	—25·5
162	57·7	72·2	103	31·5	39·4	44	5·3	6·6	—15	—20·8	—26·1
161	57·3	71·6	102	31·1	38·8	43	4·8	6·1	—16	—21·3	—26·6
160	56·8	71·1	101	30·6	38·3	42	4·4	5·5	—17	—21·7	—27·2
159	56·4	70·5	100	30·2	37·7	41	4·0	5·0	—18	—22·2	—27·7
158	56·0	70·0	99	29·7	37·2	40	3·5	4·4	—19	—22·6	—28·3
157	55·5	69·4	98	29·3	36·6	39	3·1	3·8	—20	—23·1	—28·8
156	55·1	68·8	97	28·8	36·1	38	2·6	3·3			
155	54·6	68·3	96	28·4	35·5	37	2·2	2·7			
154	54·2	67·7	95	28·0	35·0	36	1·7	2·2			

Velocity and Force of the Wind.—(*Smeaton.*)

Miles per hour.	Feet per second.	Direct force per square foot in lbs. avoirdupois.	Expression.
1	1·47	·005	Hardly perceptible.
2	2·93	·020	Just perceptible.
3	4·40	·044	
4	5·87	·079	Gentle, pleasant wind.
5	7·33	·123	
10	14·66	·492	Pleasant, brisk gale.
15	22·00	1·107	
20	29·34	1·968	Very brisk.
25	36·67	3·075	
30	44·01	4·429	High wind.
35	51·34	6·027	
40	58·68	7·873	Very high wind.
45	66·01	9·963	
50	73·35	12·300	Storm, or tempest.
60	88·02	17·715	Great storm.
80	117·36	31·490	Hurricane.
100	146·66	49·200	Hurricane that tears up trees, and carries buildings before it.

Weight of a Cubic Foot of Air.—To find the weight in pounds of a cubic foot of air at different temperatures, and under different pressures (Molesworth)—

$$W = \frac{1{\cdot}3253 \times B}{459 + T}$$

Where B is the height in inches of mercury in barometer, and T temperature Fahrenheit.

The Barometer.—If the barometer differ from 30 inches, the boiling point of water will differ from 212°. According to Wollaston, 1° Fahr. corresponds to a difference of 0·589 inches of barometric pressure. When the barometer stands at 29 inches, water boils at

210·38 Fahr. When it stands at 31 inches, water boils at 213·57.

To Measure Vertical Heights by the Barometer.

Letters denote—

$$\left.\begin{array}{l} H = \text{column of mercury} \\ T = \text{temperature of the air} \end{array}\right\} \text{at the lower station.}$$

$$\left.\begin{array}{l} h = \text{column of mercury} \\ t = \text{temperature of the air} \end{array}\right\} \text{at the higher station.}$$

l = latitude of the place.

f = vertical height, in feet, between the higher and lower station.

$$x = \log\left(\frac{H}{h} \times \frac{1}{1 + 0·0001001\ (T - t)}\right),$$

$$f = 60345·51\ x\ (1 + 0·002551 \cos 2\ l)\ (1 + 0·00208\ (T + t - 64°)).$$

If the atmosphere be very calm the observations may be made one after the other by one barometer and detached thermometer; but the least disturbance of wind requires the observations at the upper and lower stations to be made at the same time. The reduction of the columns of mercury is included in the formula.

If a measure of a height rather greater than the Aneroid will commonly show, be required—*re-set* it, thus: —When at the upper station (*within its range*), and having noted the reading carefully, touch the screw behind so as to bring back the hand a few inches (if the instrument will admit), then read off and start again. *Reverse the operation when descending.* This may add some inches of measure *approximately*.

TABLE.

Barometer Inches.	Height in feet.	Barometer Inches.	Height in feet.	Barometer Inches.	Height in feet.
31·0	0	26·8	3829	22·7	8201
30·9	85	26·7	3927	22·6	8317
30·8	170	26·6	4025	22·5	8434
30·7	255	26·5	4124	22·4	8551
30·6	341	26·4	4223	22·3	8669
30·5	427	26·3	4323	22·2	8787
30·4	513	26·2	4423	22·1	8906
30·3	600	26·1	4524	22·0	9025
30·2	687	26·0	4625	21·9	9145
30·1	774	25·9	4726	21·8	9266
30·0	862	25·8	4828	21·7	9388
29·9	950	25·7	4930	21·6	9510
29·8	1038	25·6	5033	21·5	9632
29·7	1126	25·5	5136	21·4	9755
29·6	1215	25·4	5240	21·3	9878
29·5	1304	25·3	5344	21·2	10002
29·4	1393	25·2	5448	21·1	10127
29·3	1482	25·1	5553	21·0	10253
29·2	1572	25·0	5658	20·9	10379
29·1	1662	24·9	5763	20·8	10506
29·0	1753	24·8	5869	20·7	10633
28·9	1844	24·7	5976	20·6	10760
28·8	1935	24·6	6083	20·5	10889
28·7	2027	24·5	6190	20·4	11018
28·6	2119	24·4	6297	20·3	11148
28·5	2211	24·3	6405	20·2	11278
28·4	2303	24·2	6514	20·1	11409
28·3	2396	24·1	6623	20·0	11541
28·2	2489	24·0	6733	19·9	11673
28·1	2582	23·9	6843	19·8	11805
28·0	2675	23·8	6953	19·7	11939
27·9	2769	23·7	7064	19·6	12074
27·8	2864	23·6	7175	19·5	12210
27·7	2959	23·5	7287	19·4	12346
27·6	3054	23·4	7399	19·3	12483
27·5	3149	23·3	7512	19·2	12620
27·4	3245	23·2	7625	19·1	12757
27·3	3341	23·1	7729	19·0	12894
27·2	3438	23·0	7854	18·9	12942
27·1	3535	22·9	7969	18·8	13080
27·0	3633	22·8	8085	18·7	13219
26·9	3731				

TABLE of Conducting Powers and Resistances.—(*Jenkins.*)

NAMES OF METALS.	Conducting power at 0° C.	Resistance of a Wire one foot long weighing one grain.	Resistance of a Wire one metre long weighing one gramme.	Resistance of a Wire one foot long 1-1000th inch in diameter.	Resistance of a Wire one metre long one millimetre in diameter.	Approximate percentage of variation in resistance for 1 deg. of temp. at 20°.
Silver annealed	..	0·2214	0·1544	9·936	0·01937	0·377
Silver hard drawn . . .	100·00	0·2421	0·1689	9·151	0·02103	..
Copper annealed . . .	..	0·2064	0·1440	9·718	0·02057	0·388
Copper hard drawn . .	99·55	0·2106	0·1469	9·940	0·02104	..
Gold annealed	..	0·5849	0·4080	12·52	0·02650	0·365
Gold hard drawn . . .	77·96	0·5950	0·4150	12·74	0·02697	..
Aluminium annealed . .	..	0·06822	0·05759	17·72	0·03751	..
Zinc pressed	29·02	0·5710	0·3983	32·22	0·07244	0·365
Platinum annealed. . .	..	3·536	2·464	55·09	0·1166	..
Iron annealed	16.81	1·2425	0·7522	59·40	0·1251	..
Nickel annealed . . .	13·11	1·0785	0·8666	75·78	0·1604	..
Tin pressed	12·36	1·317	0·9184	80·36	0·1701	0·365
Lead pressed	8·32	3·236	2·257	119·39	0·2527	0·387
Antimony pressed . . .	4·62	3·324	2·3295	216·0	0·4571	0·389
Bismuth pressed . . .	1·245	5·054	3·525	798·0	1·689	0·354
Mercury liquid	..	18·740	13·071	600·0	1·270	0·072
Platinum, Silver, alloy, hard or annealed .	..	4·243	2·959	143·35	0·3140	0·031
German Silver, hard or annealed	..	2·652	1·850	127·32	0·2695	0·044
Gold, Silver, alloy, hard or annealed . . .	..	2·391	1·668	66·10	0·1399	0·065

CONDUCTING POWERS OF METALS.

Coefficients for temperature (t) in deg. Cels.—(*Matthiessen.*)

METALS.	COEFFICIENTS.
Silver. . .	$c = 100 - 0{\cdot}38278\,t + 0{\cdot}0009848\,t^2$
Copper . .	$c = 100 - 0{\cdot}38701\,t + 0{\cdot}0009009\,t^2$
Gold . . .	$c = 100 - 0{\cdot}36745\,t + 0{\cdot}0008443\,t^2$
Zinc . . .	$c = 100 - 0{\cdot}37047\,t + 0{\cdot}0008274\,t^2$
Cadmium .	$c = 100 - 0{\cdot}36871\,t + 0{\cdot}0007575\,t^2$
Tin . . .	$c = 100 - 0{\cdot}36029\,t + 0{\cdot}0006136\,t^2$
Lead . . .	$c = 100 - 0{\cdot}38756\,t + 0{\cdot}0009146\,t^2$
Arsenic . .	$c = 100 - 0{\cdot}38996\,t + 0{\cdot}0008879\,t^2$
Antimony .	$c = 100 - 0{\cdot}39826\,t + 0{\cdot}0010364\,t^2$
Bismuth . .	$c = 100 - 0{\cdot}35216\,t + 0{\cdot}0005728\,t^2$
Mean of all .	$c = 100 - 0{\cdot}37647\,t + 0{\cdot}0008340\,t^2$

Conducting Powers of Solutions.

Comparison with Pure Copper = 100,000,000.

Solutions.	Temperature, Cent.	Conducting Power.
1. *Sulphate of Copper*—conc. (sp. gr. = 1·171) .	9°	5·42
Ditto, with an equal volume of water .	..	3·47
Ditto, with 3 volumes of water . . .	..	2·08
2. *Common Salt*—concentrated	13°	31·52
Ditto, with an equal volume of water .	..	23·08
Ditto, with 2 volumes of water . . .	..	17·48
Ditto, with 3 volumes of water . . .	..	13·58
3. *Sulphate of Zinc*—conc. (sp. gr. 1·441) . .	14°	5·77
Ditto, with 1 volume of water . . .	..	7·13
Ditto, with 3 volumes of water . . .	..	5·43

Dilute Sulphuric Acid.

Resistances of different strengths.

Specific gravity.	SO^3HO, in 100 parts by weight.	Temperature C.	Resistance.
1·003	0·5	16·1°	16·01
1·018	2·2	15·2	5·47
1·053	7·9	13·7	1·884
1·080	12·0	12·8	1·368
1·147	20·8	13·6	0·960
1·190	26·4	13·0	0·871
1·215	29·6	12·3	0·830
1·225	30·9	13·6	0·862
1·252	34·3	13·5	0·874
1·277	37·3	..	0·930
1·348	45·4	17·9	0·973
1·393	50·5	14·5	1·086
1·492	60·6	13·8	1·549
1·638	73·7	14·3	2·786
1·726	81·2	16·3	4·337
1·827	92·7	14·3	5·320

At very high temperatures the resistances of metals are increased, according to Müller, as follows :—

Iron Wire.		Copper Wire.		Platinum Wire.	
Temperature.	Resistance.	Temperature.	Resistance.	Temperature.	Resistance.
0° C. . . .	640	0° C.	814	0° C.	1870
21° C. . . .	691	21° C.	864	21° C.	1986
285° C. . . .	1660	Scarcely incandescent. .	2100	Barely incandescent. .	4300
Commencing to colour . .	2250	Carmine red . .	2450	Red hot . . .	4700
Dark grey . .	2460	Brick red . . .	3300	Light red. . .	5050
Scarcely incandescent. .	3050	Bright red . .	4700	Orange . . .	5400
Dark red . . .	3200	21° C.	910	Light Yellow .	6000
Bright red . .	3650			21° C.	1984
Red hot . . .	4550				
White hot . .	4880				
21° C.	727				

Simple Substances, with their Symbols, Equivalents, and Specific Gravities.

Name.	Symbol.	Equiv.	Sp. Grav.	Name.	Symbol.	Equiv.	Sp. Grav.
Aluminium .	Al	13·7	2·56	Molybdenum.	Mo	47·9	8·60
Antimony .	Sb	64·6	6·70	Nickel . .	Ni	29·5	8·80
Arsenic . .	As	37·7	5·70	Nitrogen . .	N	14·2	0·972
Bismuth . .	Bi	71·5	9·82	Osmium . .	Os	99·7	10·00
Bromine . .	Br	78·4	3·00	Oxygen . .	O	8·0	1·102
Cadmium .	Cd	55·8	8·65	Palladium .	Pd	53·3	11·35
Calcium . .	Ca	20·5	·58	Phosphorus .	P	15·9	1·77
Carbon . .	C	6·1	3·50	Platinum . .	Pt	98·8	21·50
Chlorine . .	Cl	35·5	2·44	Potassium .	K	39·2	0·865
Cobalt . .	Co	29·5	8·53	Rhodium . .	R	52·2	11·00
Copper . .	Cu	31·7	8·80	Selenium . .	Se	40·0	4·5
Fluorine . .	F	18·7	1·32	Silver . . .	Ag	108·3	10·5
Gold (Aurum)	Au	196·6	19·30	Sodium . .	Na	23·5	0·972
Hydrogen .	H	1·0	0·069	Strontium .	Sr	43·8	2·54
Iodine. . .	I	126·5	4·94	Sulphur . .	S	16·1	1·99
Iridium . .	Ir	98·5	18·68	Tellurium. .	Te	64·2	6·30
Iron . . .	Fe	28·0	7·75	Tin . . .	Sn	58·9	7·29
Lead . . .	Pb	103·7	11·35	Titanium . .	Ti	24·5	5·28
Magnesium .	Mg	12·7	1·75	Tungsten . .	W	92·0	17·00
Manganese .	Mu	26·0	8·00	Uranium . .	U	60·0	10·15
Mercury . .	Hy	200·0	13·50	Zinc . . .	Zn	32·3	7·00

TABLE containing the weight of a cubic inch, and a cubic foot, in ounces and pounds avoirdupois, and also the number of cubic inches in one pound, of the substances most used in construction.

NAMES OF BODIES.	Weight of a Cubic Foot.		Weight of a Cubic Inch.		Number of Cubic Inches in a Pound.
	In Oz.	In Lbs.	In Oz.	In Lbs.	
Copper, sheet .	8,915	557·18	5·159	·3225	3·101
Brass, cast . .	8,393	524·75	4·857	·3037	3·294
Iron, cast . . .	7,271	445·43	4·207	·263	3·802
Iron, bar . . .	7,631	476·93	4·416	·276	3·623
Lead	11,344	708·75	6·356	·4103	2·438
Steel, soft . . .	7,833	489·56	4·533	·2833	3·531
Zinc, cast . . .	7,190	449·37	4·161	·26	3·845
Tin, cast . . .	7,292	455·75	4·219	2636	3·792
Bismuth . . .	9,880	619·50	5·710	·3585	2·789
Mercury . . .	13,595	850·00	7·870	·4908	2·037
Sand	1,520	95·00	·8777	·055	18·190
Coal	1,250	78·13	·7234	·0452	22·118
Brick	2,000	125·00	1·157	·0723	13·824
Slate	2,672	167·00	1·546	·0967	10·347
Glass	2,880	180·00	1·664	·1042	9·600
Larch	544	34·00	·315	·0197	50·823
Beech	696	43.50	·403	·0252	39·724
Teak	745	46·56	·431	·0269	37·111
Mahogany . . .	852	53·25	·493	·0308	32·449
Oak	970	60·62	·561	·0351	28·503
Paraffin . . .	870	54·38	·503	·0315	31·779
Gutta-percha . .	981	61·31	·508	·0355	28·184
India-rubber . .	903	56·44	·523	·0327	19·318
Hooper's material	1176	73·50	·681	·0425	23·510
Asphalte . . .	1650	103·12	·955	·0597	16·756
Clark's Compound	1760	110·00	1·019	·0637	13·709
Hemp	1232	77·00	·713	·0446	22·422
Hemp, tarred . .	1776	111·00	1·028	·0405	24·673
Olive Oil . . .	915	57·19	·529	·0331	30·216
Linseed Oil . .	932	58·25	·539	·0337	29·655
Spirits, proof . .	927	57·93	·536	·03352	29·288
Water, distilled .	1,000	62·50	·578	·0362	27·648
Water, sea . .	1,028	64·25	·594	·0372	26·895
Tar	1,015	63·44	·587	·0367	27·242

Table of the Birmingham Wire Gauge.

No. B.W.G.	d= diam. in inches.	d^2	Sect. area in sq. ins.	No. B.W.G.	d= diam. in inches.	d^2	Sect. area in sq. ins.
1 circ. in.	1·000	1·0000	·7854	13½	·089	·0079	·00622
0000	·454	·2061	·16188	14	·083	·0069	·00541
000	·425	·1806	·14186	14½	·077	·0059	·00466
00	·380	·1444	·11341	15	·072	·0052	·00407
0	·340	·1156	·09079	15½	·068	·0046	·00363
1	·300	·0900	·07068	16	·065	·0042	·00332
2	·284	·0807	·06335	17	·058	·00336	·00264
3	·259	·0671	·05268	18	·049	·00240	·00188
4	·238	·0566	·04449	19	·042	·00176	·00138
5	·220	·0484	·03801	20	·035	·00123	·00096
5½	·211	·0445	·03497	21	·032	·00102	·00080
6	·203	·0412	·03236	22	·028	·00078	·00061
6½	·191	·0365	·02865	23	·025	·00063	·00049
7	·180	·0324	·02545	24	·022	·00048	·00038
7½	·172	·0269	·02324	25	·020	·00040	·00031
8	·165	·0272	·02138	26	·018	·00032	·00025
8½	·156	·0243	·01911	27	·016	·000256	·00020
9	·148	·0219	·01720	28	·014	·000196	·00015
9½	·141	·0199	·01561	29	·013	·000169	·00013
10	·134	·0180	·01410	30	·012	·000144	·00011
10½	·127	·0161	·01267	31	·010	·000100	·000078
11	·120	·0144	·01131	32	·009	·000081	·000063
11½	·114	·0130	·01021	33	·008	·000064	·000050
12	·109	·0119	·00933	34	·007	·000049	·000038
12½	·102	·0104	·00817	35	·005	·000025	·000019
13	·095	·0090	·00708	36	·004	·000016	·000012

Decimal Equivalents of Inches, Feet, and Yards.

Fractions of an Inch.	Decims. of an Inch.		Decims. of a Foot.	Ins.		Feet.		Yards.
$\frac{1}{16}$	·0625	=	·00521	1	=	·0833	=	·0277
$\frac{1}{8}$	·125	=	·01041	2	=	·1666	=	·0555
$\frac{3}{16}$	·1875	=	·01562	3	=	·25	=	·0833
$\frac{1}{4}$	·25	=	·02083	4	=	·3333	=	·1111
$\frac{5}{16}$	·3125	=	·02604	5	=	·4166	=	·1389
$\frac{3}{8}$	·375	=	·03125	6	=	·5	=	·1666
$\frac{7}{16}$	·4375	=	·03645	7	=	·5833	=	·1944
$\frac{1}{2}$	·5	=	·04166	8	=	·6666	=	·2222
$\frac{9}{16}$	·5625	=	·04688	9	=	·75	=	.25
$\frac{5}{8}$	·625	=	·05208	10	=	·8333	=	.2778
$\frac{11}{16}$	·6875	=	·05729	11	=	·9166	=	·3055
$\frac{3}{4}$	·75	=	·06250	12	=	1·000	=	·3333
$\frac{13}{16}$	·8125	=	·06771					
$\frac{7}{8}$	·875	=	·07291					
$\frac{15}{16}$	·9375	=	·07812					
1 inch	1·00	=	·08333					

Table of Reciprocals.

No.	Reciprocal.	No.	Reciprocal.	No.	Reciprocal.	No.	Reciprocal.	No.	Reciprocal.
2	0·5000	22	0·0455	42	0·0238	62	0·0161	82	0·0122
3	0·3333	23	0·0435	43	0·0233	63	0·0159	83	0·0120
4	0·2500	24	0·0417	44	0·0227	64	0·0156	84	0·0119
5	0·2000	25	0·0400	45	0·0222	65	0·0154	85	0·0118
6	0·1667	26	0·0385	46	0·0217	66	0·0152	86	0·0116
7	0·1429	27	0·0370	47	0·0213	67	0·0149	87	0·0115
8	0·1250	28	0·0357	48	0·0208	68	0·0147	88	0·0114
9	0·1111	29	0·0345	49	0·0204	69	0·0145	89	0·0112
10	0·1000	30	0·0333	50	0·0200	70	0·0143	90	0·0111
11	0·0909	31	0·0323	51	0·0196	71	0·0141	91	0·0110
12	0·0833	32	0·0313	52	0·0192	72	0·0139	92	0·0109
13	0·0769	33	0·0303	53	0·0189	73	0·0137	93	0·0108
14	0·0714	34	0·0294	54	0·0185	74	0·0135	94	0·0106
15	0·0667	35	0·0286	55	0·0182	75	0·0133	95	0·0105
16	0·0625	36	0·0278	56	0·0179	76	0·0132	96	0·0104
17	0·0588	37	0·0270	57	0·0175	77	0·0130	97	0·0103
18	0·0556	38	0·0263	58	0·0172	78	0·0128	98	0·0102
19	0·0526	39	0·0256	59	0·0169	79	0·0127	99	0·0101
20	0·0500	40	0·0250	60	0·0167	80	0·0125	100	0·0100
21	0·0476	41	0·0244	61	0·0164	81	0·0123		

TABLE for the Conversion of Knots of 2029 Yards into Statute Miles of 1760 Yards.

Knots.	0	1	2	3	4	5	6	7	8	9
0	. .	1·1528	2·3057	3·4585	4·6114	5·7642	6·9170	8·0699	9·2127	10·3756
10	11·5284	12·6812	13·8341	14·9869	16·1398	17·2926	18·4454	19·5983	20·7511	21·9040
20	23·0568	24·2096	25·3625	26·5153	27·6682	28·8210	29·9738	31·1267	32·2795	33·4324
30	34·5852	35·7380	36·8909	38·0437	39·1966	40·3494	41·5022	42·6551	43·8079	44·9608
40	46·1136	47·2664	48·4193	49·5721	50·7250	51·8778	53·0306	54·1835	55·3363	56·4892
50	57·6420	58·7948	59·9477	61·1005	62·2534	63·4062	64·5590	65·7119	66·8647	68·0176
60	69·1704	70·3232	71·4761	72·6289	73·7818	74·9346	76·0874	77·2403	78·3931	79·5460
70	80·6988	81·8516	83·0045	84·1573	85·3102	86·4630	87·6158	88·7687	89·9215	91·0744
80	92·2272	93·3800	94·5329	95·6857	96·8386	97·9914	99·1442	100·2971	101·4499	102·6028
90	103·7556	104·9084	106·0613	107·2141	108·3670	109·5198	110·6726	111·8255	112·9783	114·1312
100	115·2840									

TABLE for the Conversion of Statute Miles of 1760 Yards into Knots of 2029 Yards.

Statute Miles.	0	1	2	3	4	5	6	7	8	9
..	..	0·8674	1·7348	2·6023	3·4697	4·3371	5·2045	6·0719	6·9394	7 8068
10	8·6742	9·5416	10·4091	11·2765	12·1439	13·0113	13·8787	14·7462	15·6136	16·4810
20	17·3484	18·2158	19·0833	19 9507	20·8181	21·6856	22·5530	23·4204	24·2878	25·1552
30	26·0227	26·8901	27·7575	28·6249	29·4924	30·3598	31·2272	32·0946	32·9620	33·8295
40	34·6969	35·5643	36·4318	37·2992	38 1666	39·0340	39·9014	40·7689	41·6363	42·5037
50	43·3711	44·2386	45·1060	45·9734	46·8408	47·7082	48·5757	49·4431	50·3105	51·1779
60	50·0453	52·9128	53·7802	54·6476	55·5150	56·3825	57·2499	58·1173	58·9847	59·8521
70	60·7196	61·5870	62·4544	63·3218	64·1892	65·0567	65·9241	66·7915	67·8589	68·5264
80	69·3938	70·2612	71·1286	71·9960	72·8635	73·7309	74·5983	75·4657	76·3332	77·2006
90	78·0680	78·9354	79·8028	80·6703	81·5377	82·4051	83·2725	84·1400	85·0074	85·8748
100	86·7422									

O

Table to convert Yards into Knots.

Yards.	Knots.	Log.	Yards.	Knots.	Log.	Yards.	Knots.	Log.
1	·00049	·6901961	51	·02513	·4001925	101	·04978	·6970549
2	·00099	·9956352	52	·02563	·4087486	102	·05028	·7013953
3	·00148	·1702617	53	·02612	·4169732	103	·05077	·7056072
4	·00197	·2944662	54	·02661	·4250443	104	·05126	·7097786
5	·00246	·3909351	55	·02710	·4329693	105	·05175	·7139104
6	·00296	·4712917	56	·02760	·4409091	106	·05225	·7180863
7	·00345	·5378191	57	·028 9	·4485517	107	·05274	·7221401
8	·00394	·5954962	58	·02858	·4560622	108	·05323	·7261565
9	·00444	·6473830	59	·02908	·4635944	109	·05373	·7302168
10	·00493	·6928469	60	·02957	·4708513	110	·05421	·7340794
11	·00542	·7339993	61	·03006	·4779890	111	·05470	·7379873
12	·00592	·7723217	62	·03056	·4851533	112	·05520	·7419391
13	·00641	·8068580	63	·03105	·4920616	113	·05569	·7457772
14	·00690	·8388491	64	·03154	·4988617	114	·05618	·7495817
15	·00739	·8686444	65	·03203	·5055569	115	·05667	·7533532
16	·00789	·8970770	66	·03253	·5122841	116	·05717	·7571682
17	·00838	·9232440	67	·03302	·5187771	117	·05766	·7608746
18	·00887	·9479236	68	·03351	·5251744	118	·05815	·7645497
19	·00937	·9717396	69	·03401	·5316066	119	·05865	·7682680
20	·00986	·9938769	70	·03450	·5378191	120	·05914	·7718813
21	·01035	·0149403	71	·03499	·5439439	121	·05963	·7754648
22	·01085	·0354297	72	·03549	·5501060	122	·06013	·7790912
23	·01134	·0546131	73	·03598	·5560612	123	·06062	·7826159
24	·01183	·0729847	74	·03647	·5619358	124	·06111	·7861123
25	·01232	·0906107	75	·03696	·5677320	125	·06160	·7895807
26	·01282	·1078880	76	·03746	·5735678	126	·06210	·7930916
27	·01331	·1241781	77	·03795	·5792118	127	·06259	·7965050
28	·01380	·1398791	78	·03844	·5847834	128	·06308	·7998917
29	·01430	·1553360	79	·03894	·5903959	129	·06358	·8033205
30	·01479	·1699682	80	·03943	·5958268	130	·06407	·8066547
31	·01528	·1841234	81	·03992	·6011905	131	·06456	·8099635
32	·01578	·1981070	82	·04042	·6065963	132	·06506	·8133141
33	·01627	·2113876	83	·04091	·6118295	133	·06555	·8165727
34	·01676	·2242740	84	·04140	·6170003	134	·06604	·8198071
35	·01725	·2367891	85	·04189	·6221104	135	·06653	·8230175
36	·01775	·2491984	86	·04239	·6272634	136	·06703	·8262692
37	·01824	·2610248	87	·04288	·6322548	137	·06752	·8294324
38	·01873	·2725378	88	·04337	·6371894	138	·06801	·8325728
39	·01923	·2839793	89	·04387	·6421676	139	·06851	·8357540
40	·01971	·2946866	90	·04436	·6469315	140	·06900	·8388491
41	·02020	·3053514	91	·04485	·6517624	141	·06949	·8419223
42	·02070	·3159703	92	·04535	·6565173	142	·06999	·8450360
43	·02119	·3261310	93	·04584	·6612446	143	·07048	·8480659
44	·02168	·3360593	94	·04633	·6658623	144	·07097	·8510748
45	·02217	·3457657	95	·04682	·67043 4	145	·07146	·8540630
46	·02267	·3554515	96	·04732	·6750447	146	·07196	·8570912
47	·02316	·3647386	97	·04781	·6795187	147	·07245	·8600384
48	·02365	·3738311	98	·04830	·6839471	148	·07294	·8629658
49	·02415	·3829171	99	·04880	·6884198	149	·07344	·8659327
50	·02464	·3916407	100	·04929	·6927588	150	·07393	·8688207

TABLE to convert Yards into Knots—*continued.*

Yards.	Knots.	Log.	Yards.	Knots.	Log.	Yards.	Knots.	Log.
151	·07442	·8716897	201	·09906	·9958983	251	·12370	·0923697
152	·07492	·8745978	202	·09956	·9980849	252	·12420	·0941216
153	·07541	·8774289	203	·10005	·0002171	253	·12469	·0958316
154	·07590	·8802418	204	·10054	·0023389	254	·12518	·0975349
155	·07639	·8830365	205	·10103	·0044504	255	·12567	·0992316
156	·07689	·8858699	206	·10153	·0065944	256	·12617	·1009561
157	·07738	·8886287	207	·10202	·0086853	257	·12666	·1026395
158	·07787	·8913702	208	·10251	·0107662	258	·12715	·1043164
159	·07837	·8941498	209	·10301	·0128794	259	·12765	·1060208
160	·07886	·8968568	210	·10350	·0149403	260	·12814	·1076847
161	·07935	·8995469	211	·10399	·0169916	261	·12863	·1093423
162	·07985	·9022749	212	·10449	·0190747	262	·12913	·1110272
163	·08034	·9049318	213	·10498	·0211066	263	·12962	·1126720
164	·08083	·9075726	214	·10547	·0231289	264	·13011	·1143107
165	·08132	·9101974	215	·10596	·0251419	265	·13060	·1159432
166	·08182	·9128595	216	·10646	·0271865	266	·13110	·1176027
167	·08231	·9154526	217	·10695	·0291808	267	·13159	·1192229
168	·08280	·9180303	218	·10744	·0311660	268	·13208	·1208371
169	·08330	·9206450	219	·10794	·0331824	269	·13258	·1224780
170	·08379	·9231922	220	·10843	·0351495	270	·13307	·1240802
171	·08428	·9257245	221	·10892	·0371076	271	·13356	·1256764
172	·08478	·9282934	222	·10942	·0390967	272	·13406	·1272992
173	·08527	·9307963	223	·10991	·0410372	273	·13455	·1288837
174	·08576	·9332848	224	·11040	·0429691	274	·13504	·1304624
175	·08625	·9357591	225	·11089	·0448924	275	·13553	·1320354
176	·08675	·9382695	226	·11139	·0468462	276	·13603	·1336347
177	·08724	·9407157	227	·11188	·0487525	277	·13652	·1351963
178	·08773	·9431481	228	·11237	·0506504	278	·13701	·1367523
179	·08823	·9456163	229	·11287	·0525785	279	·13751	·1383343
180	·08871	·9479726	230	·11336	·0544598	280	·13800	·1398791
181	·08920	·9503649	231	·11385	·0563330	281	·13849	·1414184
182	·08970	·9527924	232	·11434	·0586158	282	·13899	·1429836
183	·09019	·9551584	233	·11484	·0600932	283	·13948	·1445119
184	·09068	·9575115	234	·11533	·0619423	284	·13997	·1460350
185	·09117	.9598520	235	·11582	·0637836	285	·14046	·1475527
186	·09167	·9622272	236	·11632	·0656544	286	·14096	·1490959
187	·09216	·9645425	237	·11681	·0674800	287	·14145	·1506030
188	·09265	·9668454	238	·11730	·0692980	288	·14194	·1521048
189	·09315	·9691829	239	·11780	·0711453	289	·14244	·1536320
190	·09364	·9714614	240	·11828	·0729113	290	·14293	·1551234
191	·09413	·9737281	241	·11877	·0747068	291	·14342	·1566097
192	·09463	·9760288	242	·11927	·0765312	292	·14392	·1581212
193	·09512	·9782718	243	·11976	·0783118	293	·14441	·1595973
194	·09561	·9805033	244	·12025	·0800851	294	·14490	·1610684
195	·09610	·9827234	245	·12074	·0818512	295	·14539	·1625345
196	·09660	·9849771	246	·12124	·0836459	296	·14589	·1640255
197	·09709	·9871745	247	·12173	·0853976	297	·14638	·1654817
198	·09758	·9893603	248	·12222	·0871423	298	·14687	·1669331
199	·09808	·9915805	249	·12272	·0889153	299	·14737	·1684091
200	·09857	·9937448	250	·12321	·0906460	300	·14786	·1698507

TABLE to convert Yards into Knots—*continued.*

Yards.	Knots.	Log.	Yards.	Knots.	Log.	Yards.	Knots.	Log.
301	·14835	·1712876	351	·17299	·2380210	401	·19763	·2958529
302	·14885	·1727488	352	·17349	·2392744	402	·19813	·2969502
303	·14934	·1741761	353	·17398	·2404993	403	·19862	·2980230
304	·14983	·1755988	354	·17447	·2417208	404	·19911	·2990931
305	·15032	·1770168	355	·17496	·2429388	405	·19960	·3001605
306	·15082	·1784589	356	·17546	·2441781	406	·20010	·3012471
307	·15131	·1798676	357	·17595	·2453893	407	·20059	·3023093
308	·15180	·1812718	358	·17644	·2465970	408	·20108	·3033689
309	·15230	·1826999	359	·17694	·2478260	409	·20158	·3044474
310	·15278	·1840665	360	·17743	·2490271	410	·20207	·3055018
311	·15327	·1854572	361	·17792	·2502248	411	·20256	·3065537
312	·15377	·1868716	362	·17842	·2514435	412	·20306	·3076244
313	·15426	·1882533	363	·17891	·2526346	413	·20355	·3086711
314	·15475	·1896307	364	·17940	·2538224	414	·20404	·3097153
315	·15524	·1910036	365	·17989	·2550070	415	·20453	·3107570
316	·15574	·1924002	366	·18039	·2562125	416	·20503	·3118174
317	·15623	·1937644	367	·18088	·2573905	417	·20552	·3128541
318	·15672	·1951244	368	·18137	·2585655	418	·20601	·3138883
319	·15722	·1965078	369	·18187	·2597611	419	·20651	·3149411
320	·15771	·1978592	370	·18236	·2609296	420	·20700	·3159703
321	·15820	·1992065	371	·18285	·2620950	421	·20749	·3169972
322	·15870	·2005769	372	·18335	·2632809	422	·20799	·3180425
323	·15919	·2019158	373	·18384	·2644400	423	·20848	·3190644
324	·15968	·2032505	374	·18433	·2655960	424	·20897	·3200839
325	·16017	·2045812	375	·18482	·2667490	425	·20946	·3211011
326	·16067	·2059348	376	·18532	·2679223	426	·20996	·3221366
327	·16116	·2072573	377	·18581	·2690691	427	·21045	·3231489
328	·16165	·2085757	378	·18630	·2702129	428	·21094	·3241589
329	·16215	·2099170	379	·18680	·2713769	429	·21144	·3251872
330	·16264	·2112274	380	·18728	·2724914	430	·21193	·3261924
331	·16313	·2125338	381	·18777	·2736262	431	·21242	·3271954
332	·16363	·2138629	382	·18827	·2747811	432	·21292	·3282165
333	·16412	·2151615	383	·18876	·2759100	433	·21341	·3292148
334	·16461	·2164562	384	·18925	·2770359	434	·21390	·3302108
335	·16510	·2177471	385	·18974	·2781589	435	·21439	·3312045
336	·16560	·2190603	386	·19024	·2793018	436	·21489	·3322162
337	·16609	·2203435	387	·19073	·2804190	437	·21538	·3332054
338	·16658	·2216229	388	·19122	·2815333	438	·21587	·3341923
339	·16708	·2229245	389	·19172	·2826674	439	·21637	·3351970
340	·16757	·2241963	390	·19221	·2837760	440	·21686	·3361795
341	·16805	·2254644	391	·19270	·2848817	441	·21735	·3371596
342	·16856	·2267545	392	·19320	·2860071	442	·21785	·3381576
343	·16905	·2280152	393	·19369	·2871072	443	·21834	·3391333
344	·16954	·2292722	394	·19418	·2882045	444	·21883	·3401069
345	·17003	·2305256	395	·19467	·2892990	445	·21932	·3410782
346	·17053	·2318008	396	·19517	·2904131	446	·21982	·3420672
347	·17102	·2330469	397	·19566	·2915020	447	·22031	·3430342
348	·17151	·2342894	398	·19615	·2925883	448	·22080	·3439991
349	·17201	·2355537	399	·19665	·2936940	449	·22130	·3449814
350	·17250	·2367891	400	·19714	·2947748	450	·22178	·3459224

TABLE to convert Yards into Knots—*continued.*

Yards.	Knots.	Log.	Yards.	Knots.	Log.	Yards.	Knots.	Log.
451	·22227	·3468808	501	·24692	·3925563	551	·27156	·4338658
452	·22277	·3478567	502	·24742	·3934348	552	·27206	·4346647
453	·22326	·3488109	503	·24791	·3942940	553	·27255	·4354462
454	·22375	·3497630	504	·24840	·3951516	554	·27304	·4362263
455	·22424	·3507131	505	·24889	·3960074	555	·27353	·4370050
456	·22474	·3516804	506	·24939	·3968790	556	·27403	·4377981
457	·22523	·3526262	507	·24988	·3977315	557	·27452	·4385740
458	·22572	·3535700	508	·25037	·3985823	558	·27501	·4393485
459	·22622	·3545310	509	·25087	·3994487	559	·27551	·4401374
460	·22671	·3554707	510	·25136	·4002962	560	·27600	·4409091
461	·22720	·3564083	511	·25185	·4011420	561	·27649	·4416794
462	·22770	·3573630	512	·25235	·4020033	562	·27699	·4424641
463	·22819	·3582966	513	·25284	·4028458	563	·27748	·4432317
464	·22868	·3592282	514	·25333	·4036866	564	·27797	·4439979
465	·22917	·3601578	515	·25382	·4045258	565	·27846	·4447628
466	·22967	·3611043	516	·25432	·4053805	566	·27896	·4455419
467	·23016	·3620298	517	·25481	·4062165	567	·27945	·4463041
468	·23065	·3629535	518	·25530	·4070508	568	·27994	·4470650
469	·23115	·3638939	519	·25580	·4079005	569	·28044	·4478400
470	·23164	·3648136	520	·25628	·4087147	570	·28093	·4485981
471	·23213	·3657313	521	·25677	·4095443	571	·28142	·4493550
472	·23263	·3666657	522	·25727	·4103891	572	·28192	·4501259
473	·23312	·3675795	523	·25776	·4112155	573	·28241	·4508801
474	·23361	·3684914	524	·25825	·4120403	574	·28290	·4516329
475	·23410	·3694014	525	·25874	·4128636	575	·28339	·4523845
476	·23460	·3703280	526	·25924	·4137020	576	·28389	·4531501
477	·23509	·3712342	527	·25973	·4145221	577	·28438	·4538990
478	·23558	·3721384	528	·26022	·4153407	578	·28487	·4546467
479	·23608	·3730592	529	·26072	·4161743	579	·28537	·4554083
480	·23657	·3739597	530	·26121	·4169898	580	·28586	·4561534
481	·23706	·3748583	531	·26170	·4178037	581	·28635	·4568972
482	·23756	·3757733	532	·26220	·4186327	582	·28685	·4576549
483	·23805	·3766682	533	·26269	·4194435	583	·28734	·4583961
484	·23854	·3775612	534	·26318	·4202529	584	·28783	·4591361
485	·23903	·3784524	535	·26367	·4210607	585	·28832	·4598748
486	·23953	·3793599	536	·26417	·4218835	586	·28882	·4606273
487	·24002	·3802474	537	·26466	·4226883	587	·28931	·4613634
488	·24051	·3811331	538	·26515	·4234916	588	·28980	·4620984
489	·24101	·3820351	539	·26565	·4243098	589	·29030	·4628470
490	·24150	·3829171	540	·26614	·4251102	590	·29078	·4635645
491	·24199	·3837974	541	·26663	·4259090	591	·29127	·4642958
492	·24249	·3846938	542	·26713	·4267227	592	·29177	·4650406
493	·24298	·3855705	543	·26762	·4275186	593	·29226	·4657694
494	·24347	·3864455	544	·26811	·4283130	594	·29275	·4664969
495	·24396	·3873186	545	·26860	·4291060	595	·29324	·4672232
496	·24446	·3882078	546	·26910	·4299137	596	·29374	·4679631
497	·24495	·3890774	547	·26959	·4307038	597	·29423	·4686870
498	·24544	·3899453	548	·27008	·4314924	598	·29472	·4694096
499	·24594	·3908292	549	·27058	·4322957	599	·29522	·4701458
500	·24643	·3916936	550	·27107	·4330815	600	·29571	·4708660

Table to convert Yards into Knots—*continued.*

Yards.	Knots.	Log.	Yards.	Knots.	Log.	Yards.	Knots.	Log.
601	·29620	·4715851	651	·32084	·5062885	701	·34549	·5384355
602	·29670	·4723175	652	·32134	·5069648	702	·34599	·5390635
603	·29719	·4730342	653	·32183	·5076265	703	·34648	·5396782
604	·29768	·4737497	654	·32232	·5082873	704	·34697	·5402919
605	·29817	·4744639	655	·32281	·5089470	705	·34746	·5409048
606	·29867	·4751916	656	·32331	·5096191	706	·34796	·5415293
607	·29916	·4759035	657	·32380	·5102768	707	·34845	·5421405
608	·29965	·4766143	658	·32429	·5109336	708	·34894	·5427508
609	·30015	·4773383	659	·32479	·5116026	709	·34944	·5433726
610	·30064	·4780468	660	·32528	·5122574	710	·34993	·5439812
611	·30113	·4787540	661	·32577	·5129111	711	·35042	·5445889
612	·30163	·4794745	662	·32627	·5135771	712	·35092	·5452081
613	·30212	·4801795	663	·32676	·5142289	713	·35141	·5458141
614	·30261	·4808833	664	·32725	·5148797	714	·35190	·5464193
615	·30310	·4815859	665	·32774	·5155294	715	·35239	·5470236
616	·30360	·4823018	666	·32824	·5161915	716	·35289	·5476394
617	·30409	·4830021	667	·32873	·5168393	717	·35338	·5482420
618	·30458	·4837014	668	·32922	·5174862	718	·35387	·5488437
619	·30508	·4844137	669	·32972	·5181453	719	·35437	·5494569
620	·30557	·4851107	670	·33021	·5187902	720	·35485	·5500448
621	·30606	·4858066	671	·33070	·5194342	721	·35534	·5506441
622	·30656	·4865155	672	·33120	·5200903	722	·35584	·5512548
623	·30705	·4872091	673	·33169	·5207324	723	·35633	·5518524
624	·30754	·4879016	674	·33218	·5213735	724	·35682	·5524492
625	·30803	·4885930	675	·33267	·5220136	725	·35731	·5530452
626	·30853	·4892974	676	·33317	·5226659	726	·35781	·5536525
627	·30902	·4899866	677	·33366	·5233041	727	·35830	·5542468
628	·30951	·4906747	678	·33415	·5239415	728	·35879	·5548403
629	·31001	·4913757	679	·33465	·5245908	729	·35929	·5554451
630	·31050	·4920616	680	·33514	·5252263	730	·35978	·5560370
631	·31099	·4927464	681	·33563	·5258608	731	·36027	·5566281
632	·31149	·4934441	682	·33613	·5265073	732	·36077	·5572304
633	·31198	·4941268	683	·33662	·5271399	733	·36126	·5578199
634	·31247	·4948083	684	·33711	·5277716	734	·36175	·5584085
635	·31296	·4954888	685	·33760	·5284024	735	·36224	·5589964
636	·31346	·4961821	686	·33810	·5290452	736	·36274	·5595954
637	·31395	·4968605	687	·33859	·5296741	737	·36323	·5601817
638	·31444	·4975378	688	·33908	·5303022	738	·36372	·5607672
639	·31494	·4982278	689	·33958	·5309421	739	·36422	·5613638
640	·31543	·4989030	690	·34007	·5315683	740	·36471	·5619477
641	·31592	·4995771	691	·34056	·5321936	741	·36520	·5625308
642	·31642	·5002639	692	·34106	·5328308	742	·36570	·5631250
643	·31691	·5009359	693	·34155	·5334543	743	·36619	·5637065
644	·31740	·5016069	694	·34204	·5340769	744	·36668	·5642872
645	·31789	·5022769	695	·34253	·5346986	745	·36717	·5648672
646	·31839	·5029594	696	·34303	·5353321	746	·36767	·5654582
647	·31888	·5036273	697	·34352	·5359520	747	·36815	·5660248
648	·31937	·5042941	698	·34401	·5365711	748	·36865	·5666142
649	·31987	·5049735	699	·34451	·5372018	749	·36915	·5672029
650	·32035	·5056247	700	·34500	·5378191	750	·36964	·5677790

TABLE to convert Yards into Knots—*continued.*

Yards.	Knots.	Log.	Yards.	Knots.	Log.	Yards.	Knots.	Log.
751	·37013	·5683543	801	·39477	·5963441	851	·41942	·6226491
752	·37063	·5689406	802	·39527	·5968939	852	·41992	·6231666
753	·37112	·5695144	803	·39576	·5974319	853	·42041	·6236730
754	·37161	·5700874	804	·39625	·5979693	854	·42090	·6241789
755	.37210	·5706597	805	·39674	·5985060	855	·42139	·6246842
756	·37264	·5712895	806	·39724	·5990530	856	·42189	·6251992
757	·37309	·5718136	807	·39773	·5995884	857	·42238	·6257033
758	·37358	·5723836	808	·39822	·6001231	858	·42287	·6262069
759	·37408	·5729645	809	·39872	·6006680	859	·42337	·6267201
760	·37457	·5735330	810	·39921	·6012014	860	·42385	·6272122
761	·37506	·5741007	811	·39970	·6017341	861	·42434	·6277140
762	·37556	·5746793	812	·40 20	·6022771	862	·42484	·6282254
763	·37605	·5752456	813	·40069	·6028085	863	·42533	·6287260
764	·37654	·5758111	814	·40118	·6033393	864	·42582	·6292261
765	·37703	·5763759	815	·40167	·6038694	865	·42631	·6297255
766	·37753	·5769515	816	·40217	·6044097	866	·42681	·6302346
767	·37803	·5775263	817	·40266	·6049385	867	·42730	·6307329
768	·37851	·5780774	818	·40315	·6054667	868	·42779	·6312306
769	·37901	·5786507	819	·40365	·6060050	869	·42829	·6317379
770	·37950	·5792118	820	·40414	·6065318	870	·42878	·6322345
771	·37999	·5797722	821	·40463	·6070581	871	·42927	·6327305
772	·38049	·5803432	822	·40513	·6075944	872	·42977	·6332361
773	·38098	·5809022	823	40562	·6081194	873	·43026	·6337310
774	·38147	·58 4604	824	·40611	·6086437	874	·43075	·6342253
775	·38196	·5820179	825	·40660	·6091674	875	·43124	·6347190
776	·38246	·5825860	826	·40710	·6097011	876	·43174	.6352223
777	·38295	·5831421	827	·40759	·6102235	877	·43223	·63 7149
778	·38344	·5836974	828	·408 8	·6107453	878	·43272	· 362070
779	·38394	·5842634	829	·40858	·6112771	879	·43322	·6367085
780	·38443	·5848173	830	·40907	·6117976	880	·43371	·6371994
781	·38492	·5853705	831	·40956	·6123175	881	·43420	·6376898
782	·38542	·5859342	832	·41006	·6128474	882	·43470	·6381896
783	·38591	·5864860	833	·41055	·6133661	883	·43519	·6386789
784	·38640	·5870371	834	·41104	·6138841	884	·43568	·6391676
785	·38689	·5875875	835	·41153	·6144015	885	·43617	·63 6558
786	·38739	·5881484	836	·41203	·6149288	886	·43667	·64 1534
787	·38788	·5886974	837	·41252	·6154450	887	·43716	·6406404
788	·38837	·5892457	838	·41301	·6159606	888	·43765	·6411269
789	·38887	·5898044	839	·41351	·6164860	889	·43815	·6416228
790	·38935	·5903402	840	·41400	·6170003	890	·43864	·6421082
791	·38984	·5908864	841	·41449	·6175141	891	·43913	·6425931
792	·39 34	·5914431	842	·41499	·6180376	892	·43963	·6430873
793	·39083	·5919879	843	·41 49	·6185606	893	·44012	·6435711
794	·39132	·5925320	844	·41597	·6190620	894	·44 61	·6440543
795	·39181	·5930755	845	·41646	·6195733	895	·44110	·6445371
796	·39231	·5936294	846	·41696	·6200944	896	·44160	·6450291
797	·39280	·5941715	847	·41745	·62 6045	897	·44209	·6455107
798	·39329	·5947129	848	·41794	·6211139	898	·44258	·6459918
799	·39383	·5953088	849	·41844	·6216332	899	·44308	·6464821
800	·39428	·5958047	850	·41893	·6221415	900	·44357	·6469622

TABLE to convert Yards into Knots—*continued.*

Yards.	Knots.	Log.	Yards.	Knots.	Log.	Yards.	Knots.	Log.
901	·44406	·6474417	951	·46870	·6708950	1001	·49334	·6931463
902	·44456	·6479304	952	·46920	·6713580	1002	·49384	·6935863
903	·44505	·6484088	953	·46969	·6718113	1003	·49433	·6940170
904	·44554	·6488867	954	·47018	·6722642	1004	·49482	·6944472
905	·44603	·6493641	955	·47067	·6727165	1005	·49531	·6948771
906	·44653	·6498506	956	·47117	.6731776	1006	·49581	·6953153
907	·44702	·6503270	957	·47166	·6736290	1007	·49630	·6957443
908	·44751	·6508027	958	·47215	·6740800	1008	·49679	·6961728
909	·44801	·6512877	959	·47265	·6745397	1009	·49729	·6966097
910	·44850	·6517624	960	·47314	·6749897	1010	·49778	·6970374
911	·44899	·6522367	961	·47363	·6754392	1011	·49827	·6974647
912	·44949	·6527200	962	·47413	·6758974	1012	·49877	·6979003
913	·44998	·6531932	963	·47462	·6763460	1013	·49926	·6983268
914	·45047	·6536659	964	·47511	·6767942	1014	·49975	·6987528
915	·45096	·6541380	965	·47560	·6772418	1015	·50024	·6991784
916	·45146	·6546193	966	·47610	·6776982	1016	.50074	·6996123
917	·45195	·6550904	967	·47659	·6781449	1017	·50123	·7000371
918	·45244	·6555610	968	·47708	·6785912	1018	·50172	·7004614
919	·45294	·6560407	969	·47758	·6790461	1019	·50222	·7008940
920	·45343	·6565103	970	·47807	·6794915	1020	·50271	·7013175
921	·45392	·6569793	971	·47856	·6799364	1021	·50320	·7017406
922	·45442	·6574574	972	·47906	·6803899	1022	·50370	·7021720
923	·454[illegible]1	·6579255	973	·47955	·6808339	1023	·50419	·7025942
924	·45540	·6583930	974	·48004	·6812774	1024	·50468	·7030161
925	·45589	·6588601	975	·48053	·6817205	1025	·50517	·7034376
926	·45639	·6593361	976	·48103	·6821722	1026	·50567	·7038672
927	·45688	·6598021	977	·48152	·6826143	1027	·50616	·7042878
928	·45737	·6602677	978	·48201	·6830560	1028	·50665	·7047080
929	·45787	·6607422	979	·48251	·6835063	1029	·50715	·7051364
930	·45835	·6611972	980	·48300	·6839471	1030	·50764	·7055558
931	·45884	·6616613	981	·48349	·6843875	1031	·50813	·7059748
932	·45934	·6621343	982	·48399	·6848364	1032	·50863	·7064020
933	·45983	·6625973	983	·48448	·6852759	1033	·50912	·7068202
934	·46032	·6630598	984	·48497	·6857149	1034	·50961	·7072379
935	·46081	·6635219	985	·4[illegible]546	·6861535	1035	·51010	·7076553
936	·46131	·6639929	986	·48596	·6866005	1036	·51060	·7080808
937	·46180	·6644539	987	·48645	·6870382	1037	·51109	·7084974
938	·46229	·6649145	988	·48694	·6874755	1038	·51158	·7089136
939	·46279	·6653840	989	·48744	·6879212	1039	·51208	·7093378
940	·46328	·6658436	990	·48793	·6883575	1040	·51257	·7097532
941	·46377	·6663027	991	·48842	·6887934	1041	·51306	·7101682
942	·4[illegible]427	·6667706	992	·48892	·6892378	1042	·51356	·7105912
943	·46476	·6672287	993	·48941	·6896728	1043	·51405	·7110054
944	·46525	·6676864	994	·48990	·6901074	1044	·51454	·7114191
945	·46574	·6681435	995	·49039	·6905416	1045	·51503	·7118325
946	·46624	·6686095	996	·49089	·6[illegible]09842	1046	·51553	·7122539
947	·46673	·6690657	997	·49138	·6914175	1047	·51602	·7126665
948	·46722	·669[illegible]214	998	·49187	·6918503	1048	·51651	·7130787
949	·46772	·6699859	999	·49[illegible]37	·6922916	1049	·51701	·7134989
950	·46821	·6704407	1000	·49285	·6927148	1050	·51750	·7139104

TABLE to convert Yards into Knots—*continued.*

Yards.	Knots.	Log.	Yards.	Knots.	Log.	Yards.	Knots.	Log.
1051	·51799	·7143214	1101	·54263	·7345038	1151	·56727	·7537898
1052	·51849	·7147404	1102	·54313	·7349038	1152	·56777	·7541724
1053	·51898	·7151506	1103	·54362	·7352954	1153	·56826	·7545471
1054	·51947	·7155605	1104	·54411	·7356867	1154	·56875	·7549214
1055	·51996	·7159699	1105	·54460	·7360776	1155	·56924	·7552954
1056	·52046	·7163874	1106	·54510	·7364762	1156	·56974	·7556767
1057	·52095	·7167960	1107	·54559	·7368664	1157	·57023	·7560501
1058	·52144	·7172043	1108	·54608	·7372563	1158	·57072	·7564231
1059	·52194	·7176206	1109	·54658	·7376537	1159	·57122	·7568034
1060	·52242	·7180198	1110	·54707	·7380429	1160	·57171	·7571758
1061	·52291	·7184269	1111	·54756	·7384317	1161	·57220	·7575479
1062	·52341	·7188420	1112	·54806	·7388281	1162	·57270	·7579272
1063	·52390	·7192484	1113	·54855	·7392162	1163	·57319	·7582986
1064	·52439	·7196544	1114	·54904	·7396040	1164	·57368	·7586697
1065	·52488	·7200600	1115	·54953	·7399914	1165	·57417	·7590405
1066	·52538	·7204735	1116	·55003	·7403864	1166	·57467	·7594185
1067	·52587	·7208784	1117	·55052	·7407731	1167	·57516	·7597887
1068	·52636	·7212829	1118	·55101	·7411595	1168	·57565	·7601585
1069	·52686	·7216952	1119	·55151	·7415534	1169	·57615	·7605356
1070	·52735	·7220990	1120	·55200	·7419391	1170	·57664	·7609048
1071	·52784	·7225023	1121	·55249	·7423244	1171	·57713	·7612737
1072	·52834	·7229135	1122	·55299	·7427173	1172	·57763	·7616497
1073	·52883	·7233161	1123	·55348	·7431019	1173	·57812	·7620180
1074	·52932	·7237183	1124	·55417	·7436430	1174	·57861	·7623859
1075	·52981	·7241202	1125	·55446	·7438702	1175	·57910	·7627536
1076	·53031	·7245298	1126	·55496	·7442617	1176	·57960	·7631284
1077	·53080	·7249309	1127	·55545	·7446450	1177	·58009	·7634954
1078	·53129	·7253316	1128	·55594	·7450279	1178	·58058	·7638621
1079	·53179	·7257402	1129	·55644	·7454183	1179	·58108	·7642359
1080	·53228	·7261401	1130	·55692	·7457928	1180	·58157	·7646020
1081	·53277	·7265398	1131	·55741	·7461748	1181	·58206	·7649678
1082	·53327	·7269472	1132	·55791	·7465641	1182	·58256	·7653407
1083	·53376	·7273460	1133	·55840	7469454	1183	·58305	·7657058
1084	·53425	·7277445	1134	·55889	·7473263	1184	·58354	·7660706
1085	·53474	·7281427	1135	·55938	·7477069	1185	·58403	·7664352
1086	·53524	·7285486	1136	·55988	·7480950	1186	·58453	·7668068
1087	·53573	·7289460	1137	·56037	·7484749	1187	·58502	·7671707
1088	·53622	·7293430	1138	·56086	·7488545	1188	·58551	·7675343
1089	·53672	·7297478	1139	·56136	·7492415	1189	·58601	·7679050
1090	·53721	·7301441	1140	·56185	·7496204	1190	·58650	·7682680
1091	·53770	·7305400	1141	·56234	·7499990	1191	·58699	·7686307
1092	·53820	·7309437	1142	·56284	·7503850	1192	·58749	·7690005
1093	·53869	·7313389	1143	·56333	·7507629	1193	·58798	·7693626
1094	·53918	·7317338	1144	·56382	·7511405	1194	·58850	·7696505
1095	·53967	·7321283	1145	·56431	·7515177	1195	·58896	·7700858
1096	·54017	·7325305	1146	·56481	·7519024	1196	·58946	·7704543
1097	·54 66	·7329242	1147	·56530	·7522790	1197	·58995	·7708152
1098	·54115	·7333177	1148	·56579	·7526553	1198	·59044	·7711758
1099	·54165	·7337187	1149	·56629	·7530369	1199	·59094	·7715434
1100	·54214	·7341115	1150	·56678	·7534145	1200	·59142	·7718960

TABLE to convert Yards into Knots—*continued.*

Yards.	Knots.	Log.	Yards.	Knots.	Log.	Yards.	Knots.	Log.
1201	·59191	·7722557	1251	·61656	·7899753	1301	·64120	·8069935
1202	·59241	·7726224	1252	·61706	·7903274	1302	·64170	·8073320
1203	·59290	·7729815	1253	·61755	·7906721	1303	·64219	·8076635
1204	·59339	·7733402	1254	·61804	·7910166	1304	·64268	·8079948
1205	·59388	·7736987	1255	·61853	·7913608	1305	·64317	·8083258
1206	·59438	·7740642	1256	·61903	·7917117	1306	·64367	·8086633
1207	·59487	·7744221	1257	·61952	·7920553	1307	·64416	·8089938
1208	·59536	·7747797	1258	·62001	·7923987	1308	·64465	·8093240
1209	·59586	·7751442	1259	·62051	·7927488	1309	·64515	·8096607
1210	·59635	·7755012	1260	·62100	·7930916	1310	·64564	·8099904
1211	·59684	·7758579	1261	·62149	·7934341	1311	·64613	·8103199
1212	·59734	·7762216	1262	·62199	·7937834	1312	·64663	·8106558
1213	·59783	·7765777	1263	·62248	·7941254	1313	·64712	·8109848
1214	·59832	·7769335	1264	·62297	·7944671	1314	·64761	·8113135
1215	·59881	·7772890	1265	·62346	·7948086	1315	·64810	·8116420
1216	·59931	·7776515	1266	·62396	·7951567	1316	·64860	·8119769
1217	·59980	·7780065	1267	·62445	·7954977	1317	·64909	·8123049
1218	·60029	·7783611	1268	·62494	·7958383	1318	·64958	·8126326
1219	·60079	·7787227	1269	·62544	·7961857	1319	·65008	·8129668
1220	·60128	·7790768	1270	·62592	·7965188	1320	·65057	·8132940
1221	·60177	·7794305	1271	·62641	·7968587	1321	·65106	·8136210
1222	·60227	·7797912	1272	·62691	·7972052	1322	·65156	·8139544
1223	·60276	·7801444	1273	·62740	·7975445	1323	·65205	·8142809
1224	·60325	·7804973	1274	·62789	·7978836	1324	·65254	·8146071
1225	·60374	·7808500	1275	·62838	·7982224	1325	·65303	·8149331
1226	·60424	·7812095	1276	·62888	·7985678	1326	·65353	·8152655
1227	·60473	·7815615	1277	·62937	·7989060	1327	·65402	·8155910
1228	·60522	·7819133	1278	·62987	·7992509	1328	·65451	·8159163
1229	·60572	·7822719	1279	·63036	·7995886	1329	·65501	·8162479
1230	·60621	·7826231	1280	·63085	·7999261	1330	·65550	·8165727
1231	·60670	·7829740	1281	·63134	·8002633	1331	·65599	·8168972
1232	·60720	·7833318	1282	·63184	·8006071	1332	·65649	·8172281
1233	·60769	·7836821	1283	·63233	·8009438	1333	·65698	·8175521
1234	·60818	·7840321	1284	·63282	·8012802	1334	·65747	·8178759
1235	·60867	·7843819	1285	·63331	·8016163	1335	·65796	·8181995
1236	·60917	·7847385	1286	·63381	·8019591	1336	·65846	·8185294
1237	·60966	·7850877	1287	·63430	·8022262	1337	·65895	·8188525
1238	·61015	·7854366	1288	·63479	·8026301	1338	·65944	·8191753
1239	·61065	·7857924	1289	·63529	·8029720	1339	·65994	·8195045
1240	·61114	·7861407	1290	·63578	·8033069	1340	·66042	·8198202
1241	·61163	·7864888	1291	·63627	·8036414	1341	·66091	·8201423
1242	·61213	·7868437	1292	·63677	·8039826	1342	·66141	·8204708
1243	·61262	·7871912	1293	·63726	·8043167	1343	·66190	·8207924
1244	·61317	·7875809	1294	·63775	·8046505	1344	·66239	·8211138
1245	·61360	·7878854	1295	·63824	·8049840	1345	·66288	·8214349
1246	·61410	·7882391	1296	·63874	·8053241	1346	·66338	·8217624
1247	·61459	·7885855	1297	·63923	·8056571	1347	·66387	·8220830
1248	·61508	·7889316	1298	·63972	·8059899	1348	·66438	·8224166
1249	·61558	·7892845	1299	·64022	·8063292	1349	·66486	·8227302
1250	·61607	·7896301	1300	·64071	·8066615	1350	·66535	·8230502

TABLE to convert Yards into Knots—*continued.*

Yards.	Knots.	Log.	Yards.	Knots.	Log.	Yards.	Knots.	Log.
1351	·66584	·8233699	1401	·69049	·8391574	1451	·71513	.8543850
1352	·66634	·8236959	1402	·69099	·8394718	1452	·71563	·8546885
1353	·66683	·8240151	1403	·69148	·8397796	1453	·71612	·8549858
1354	·66732	·8243341	1404	·69197	·8400873	1454	·71661	·8552829
1355	·66781	·8246529	1405	·69246	·8403947	1455	·71710	·8555797
1356	·66831	·8249780	1406	·69296	·8407082	1456	·71760	·8558824
1357	·66880	·8252963	1407	·69345	·8410152	1457	·71809	·8561789
1358	·66929	·8256143	1408	·69394	·8413219	1458	·71858	·8564751
1359	·66979	·8259387	1409	·69444	·8416347	1459	·71908	·8567772
1360	·67028	·8262563	1410	·69492	·8419348	1460	·71957	·8570730
1361	·67077	·8265736	1411	·69541	·8422409	1461	·72006	·8573687
1362	·67127	·8268972	1412	·69591	·8425531	1462	·72056	·8576701
1363	·67176	·8272141	1413	·69640	·8428588	1463	·72105	·8579654
1364	·67225	·8275308	1414	·69689	·8431642	1464	·72154	·8582604
1365	·67274	·8278473	1415	·69738	·8434695	1465	·72203	·8585552
1366	·67324	·8281699	1416	·69788	·8437808	1466	·72253	·8588559
1367	·67373	·8284859	1417	·69837	·8440856	1467	·72302	·8591503
1368	·67422	·8288016	1418	·69886	·8443902	1468	·72351	·8594445
1369	·67472	·8291236	1419	·69936	·8447008	1469	·72391	·859[illegible]846
1370	·67521	·8294389	1420	·69985	·8450050	1470	·72450	·8600384
1371	·67570	·8297539	1421	·70034	·8453089	1471	·72499	·8603320
1372	·67620	·8300752	1422	·70084	·8456189	1472	·72549	·8606314
1373	·67669	·8303898	1423	·70133	·8459224	1473	·72598	·8609247
1374	·67718	·8307041	1424	·70182	·8462257	1474	·72647	·8612177
1375	·67767	·8310183	1425	·70231	·8465289	1475	·72696	·8615105
1376	·67817	·8313386	1426	·70281	·8468379	1476	·72746	·8618091
1377	·67866	·8316523	1427	·70330	·8471406	1477	·72795	·8621016
1378	·67915	·8319657	1428	·70379	·8474431	1478	·72844	·8623938
1379	·67965	·8322853	1429	·70429	·8477515	1479	·72894	·8626918
1380	·68014	·8325983	1430	·70478	·8480536	1480	·72942	·8629777
1381	·68063	·8329111	1431	·70527	·8483554	1481	·72991	·8632693
1382	·68113	·8332300	1432	·70577	·8486632	1482	·73041	·8635667
1383	·68162	·8335423	1433	·70626	·8489646	1483	·73090	·8638580
1384	·68211	·8338544	1434	·70675	·8492658	1484	·73139	·8641490
1385	·68260	·8341663	1435	·70724	·8495668	1485	·73188	·8644399
1386	·68310	·8344843	1436	·70774	·8498737	1486	·73238	·8647365
1387	·68359	·8347957	1437	·70823	·8501743	1487	·73287	·8650269
1388	·68408	·8351069	1438	·70872	·8504747	1488	·73336	·8653172
1389	·68458	·8354242	1439	·70922	·8507810	1489	·73386	·8656132
1390	·68507	·8357349	1440	·70971	·8510809	1490	·73435	·8659031
1391	·68556	·8360455	1441	·71020	·8513807	1491	·73484	·8661928
1392	·68606	·8363621	1442	·71070	·8516863	1492	·73534	·8664882
1393	·68655	·8366722	1443	·71119	·8519856	1493	·73582	·8667716
1394	·68704	·8369820	1444	·71168	·8529848	1494	·73632	·8670666
1395	·68753	·8372917	1445	·71217	·8522837	1495	·73681	·8673555
1396	·68803	·8376074	1446	·71267	·8528885	1496	·73731	·8676501
1397	·68852	·8379166	1447	·71316	·8531870	1497	·73780	·8679387
1398	·68901	·8382255	1448	·71365	·8534853	1498	·73829	·8682270
1399	·68951	·8385406	1449	·71415	·8537894	1499	·73879	·8685210
1400	·69000	·8388491	1450	·71464	·8540873	1500	·73928	·8688090

TABLE to convert Yards into Knots—*continued.*

Yards.	Knots.	Log.	Yards.	Knots.	Log.	Yards.	Knots.	Log.
1501	·73977	·8690967	1551	·76441	·8833264	1601	·78906	·8971100
1502	·74027	·8693901	1552	·76491	·8836103	1602	·78956	·8973851
1503	·74076	·8696775	1553	·76540	·8838885	1603	·79005	·8976546
1504	·74125	·8699647	1554	·76589	·8841664	1604	·79054	·8979238
1505	·74174	·8702517	1555	·76638	·8844442	1605	·79103	·8981930
1506	·74224	·8705444	1556	·76688	·8847274	1606	·79153	·8984674
1507	·74273	·8708310	1557	·76737	·8850048	1607	·79202	·8987361
1508	·74322	·8711174	1558	·76786	·8852820	1608	·79251	·8990048
1509	·74372	·8714095	1559	·76836	·8855647	1609	·79301	·8992787
1510	·74421	·8716955	1560	·76885	·8858416	1610	·79349	·8995415
1511	·74470	·8719814	1561	·76934	·8861183	1611	·79398	·8998096
1512	·74520	·8722728	1562	·76984	·8864005	1612	·79448	·9000830
1513	·74569	·8725583	1563	·77033	·8866768	1613	·79497	·9003507
1514	·74618	·8728436	1564	·77082	·8869530	1614	·79546	·9006183
1515	·74667	·8731287	1565	·77131	·8872290	1615	·79595	·9008858
1516	·74717	·8734194	1566	·77181	·8875104	1616	·79645	·9011585
1517	·74766	·8737041	1567	·77230	·8877860	1617	·79694	·9014256
1518	·74815	·8739887	1568	·77279	·8880615	1618	·79743	·9016926
1519	·74865	·8742788	1569	·77329	·8883424	1619	·79793	·9019648
1520	·74914	·8745630	1570	·77378	·8886175	1620	·79842	·9022314
1521	·74963	·8748470	1571	·77427	·8888924	1621	·79891	·9024979
1522	·75013	·8751365	1572	·77477	·8891728	1622	·79941	·9027696
1523	·75 62	·8754201	1573	·77526	·8894474	1623	·79990	·9030357
1524	·75111	·8757035	1574	·77575	·8897218	1624	·08039	·9033017
1525	·75160	·8759868	1575	·77624	·8899960	1625	·80088	·9035674
1526	·75210	·8762756	1576	·77674	·8902757	1626	·80138	·9038385
1527	·75259	·8765584	1577	·77723	·8905496	1627	·8 187	·9041040
1528	·75308	·8768411	1578	·77772	·8908233	16:8	·80236	·9043693
1529	·75358	·8771294	1579	·77822	·8911024	1629	·80286	·9046398
1530	·75407	·8774117	1580	·77871	·8913758	1630	·80335	·9049048
1531	·75456	·8776938	1581	·77920	·8916489	1631	·80384	·9051696
1532	·75506	·8779815	1582	·77970	·8919275	1632	·80434	·9054397
1533	·75555	·8782632	1583	·78019	·8922004	1633	·80483	·9057042
1534	·75604	·8785448	1584	·78068	·8924731	1634	·80532	·9059685
1535	·75653	·8788262	1585	·78117	·8927456	1635	·80581	·9062327
1536	·75703	·8791131	1586	·78167	·8930234	1636	·80631	·9065020
1537	·75752	·8793941	1587	·78216	·8932956	1637	·80680	·9067659
1538	·75801	·8796749	1588	·78265	·8935676	1638	80729	·9070296
1539	·75851	·8799613	1589	·78315	·8938450	1639	·80779	·9072985
1540	·75899	·8802361	1590	·78364	·8941166	1640	·80828	·9075618
1541	·75948	·8805163	1591	·78415	·8943991	1641	·80877	·9078250
1542	·75998	·8808022	1592	·78463	·8946649	1642	·80927	·9080934
1543	·76047	·8810821	1593	·78512	·8949360	1643	·80976	·9083563
1544	·76096	·8813618	1594	·78561	·8952070	1644	·81025	·9086190
1545	·76145	·8816414	1595	·78610	·8954778	1645	·81074	·9088816
1546	·76195	·8819265	1596	·78660	·8957539	1646	·81124	·9091494
1547	·76244	·8822057	1597	·78709	·8960244	1647	·81173	·9094116
1548	·76293	·8824847	1598	·78758	·8962947	1648	·81222	·9096737
1549	·76343	·8827692	1599	·78808	·8965703	1649	·81272	·9099409
1550	·76392	·8830479	1600	·78857	·8968403	1650	·81321	·9102027

TABLE to convert Yards into Knots—*continued.*

Yards.	Knots.	Log.	Yards.	Knots.	Log.	Yards.	Knots.	Log.
1651	·81370	·9104643	1701	·83834	·9234202	1751	·86298	·9360007
1652	·81420	·9107311	1702	·83884	·9236791	1752	·86348	·9362523
1653	·81469	·9109924	1703	·83933	·9239327	1753	·86397	·9364987
1654	·81518	·9112535	1704	·83982	·9241862	1754	·86446	·9367449
1655	·81567	·9115145	1705	·84031	·9244395	1755	·86495	·9369910
1656	·81617	·9117806	1706	·84081	·9246979	1756	·86545	·9372420
1657	·81666	·9120413	1707	·84130	·9249509	1757	·86594	·9374878
1658	·81715	·9123018	1708	·84179	·9252038	1758	·86643	·9377335
1659	·81765	·9125674	1709	·84229	·9254616	1759	·86693	·9379840
1660	·81814	·9128276	1710	·84278	·9257142	1760	·86742	·9382294
1661	·81863	·9130877	1711	·84327	·9259667	1761	·86791	·9384747
1662	·81913	·9133528	1712	·84377	·9262241	1762	·86841	·9387248
1663	·81962	·9136125	1713	·84426	·9264762	1763	·86890	·9389698
1664	·82011	·9138721	1714	·84475	·9267282	1764	·86939	·9392146
1665	·82060	·9141315	1715	·84524	·9269800	1765	·86988	·9394593
1666	·82110	·9143961	1716	·84574	·9272369	1766	·87038	·9397089
1667	·82159	·9146551	1717	·84623	·9274884	1767	·87087	·9399533
1668	·82208	·9149141	1718	·84672	·9277398	1768	·87136	·9401976
1669	·82258	·9151781	1719	·84722	·9279962	1769	·87186	·9404468
1670	·82307	·9154368	1720	·84771	·9282473	1770	·87235	·9406908
1671	·82356	·9156952	1721	·84820	·9284983	1771	·87284	·9409346
1672	·82406	·9159588	1722	·84870	·9287542	1772	·87334	·9411834
1673	·82455	·9162170	1723	·84919	·9290049	1773	·87383	·9414270
1674	·82504	·9164750	1724	·84968	·9292554	1774	·87432	·9416704
1675	·82553	·9167329	1725	·85017	·9295058	1775	·87481	·9419137
1676	·82603	·9169958	1726	·85067	·9297611	1776	·87531	·9421619
1677	·82652	·9172534	1727	·85116	·9300112	1777	·87580	·9424049
1678	·82701	·9175108	1728	·85165	·9302612	1778	·87629	·9426479
1679	·82751	·9177733	1729	·85215	·9305160	1779	·87679	·9428956
1680	·82799	·9180251	1730	·85264	·9307657	1780	·87728	·9431382
1681	·82848	·9182820	1731	·85313	·9310152	1781	·87777	·9433807
1682	·82898	·9185441	1732	·85363	·9312697	1782	·87827	·9436280
1683	·82947	·9188007	1733	·85412	·9315189	1783	·87876	·9438703
1684	·82996	·9190572	1734	·85461	·9317680	1784	·87925	·9441124
1685	·83045	·9193135	1735	·85510	·9320169	1785	·87974	·9443543
1686	·83095	·9195749	1736	·85560	·9322708	1786	·88024	·9446011
1687	·83144	·9198309	1737	·85609	·9325194	1787	·88073	·9448428
1688	·83193	·9200868	1738	·85658	·9327679	1788	·88122	·9450843
1689	·83243	·9203477	1739	·85708	·9330214	1789	·88172	·9453307
1690	·83292	·9206033	1740	·85757	·9332696	1790	·88221	·9455720
1691	·83341	·9208587	1741	·85806	·9335177	1791	·88270	·9458131
1692	·83391	·9211192	1742	·85856	·9337707	1792	·88320	·9460591
1693	·83440	·9213743	1743	·85905	·9340184	1793	·88369	·9462999
1694	·83489	·9216293	1744	·85954	·9342661	1794	·88418	·9465407
1695	·83538	·9218841	1745	·86003	·9345136	1795	·88467	·9467813
1696	·83588	·9221439	1746	·86053	·9347660	1796	·88517	·9470267
1697	·83637	·9223984	1747	·86102	·9350132	1797	·88566	·9472670
1698	·83686	·9226528	1748	·86151	·9352603	1798	·88615	·9475072
1699	·83736	·9229122	1749	·86201	·9355123	1799	·88665	·9477522
1700	·83785	·9231663	1750	·86249	·9357541	1800	·88714	·9479922

Table to convert Yards into Knots—*continued.*

Yards.	Knots.	Log.	Yards.	Knots.	Log.	Yards.	Knots.	Log.
1801	·88763	·9482320	1851	·91227	·9601234	1901	·93691	·9716979
1802	·88813	·9484765	1852	·91277	·9603614	1902	·93741	·9719296
1803	·88862	·9487161	1853	·91326	·9605944	1903	·93790	·9721565
1804	·88911	·9489555	1854	·91375	·9608274	1904	·93839	·9723834
1805	·88960	·9491948	1855	·91424	·9610602	1905	·93888	·9726101
1806	·89010	·9494388	1856	·91474	·9612977	1906	·93938	·9728413
1807	·89059	·9496778	1857	·91523	·9615302	1907	·93987	·9730678
1808	·89108	·9499167	1858	·91572	·9617627	1908	·94036	·9732941
1809	·89158	·9501603	1859	·91622	·9619998	1909	·94086	·9735250
1810	·89207	·9503989	1860	·91671	·9622320	1910	·94135	·9737511
1811	·89256	·9506374	1861	·91720	·9624640	1911	·94184	·9739771
1812	·89306	·9508806	1862	·91770	·9627007	1912	·94234	·9742076
1813	·89355	·9511189	1863	·91819	·9629326	1913	·94283	·9744334
1814	·89404	·9513569	1864	·91868	·9631643	1914	·94332	·9746590
1815	·89453	·9515949	1865	·91917	·9633958	1915	·94381	·9748846
1816	·89503	·9518376	1866	·91967	·9636320	1916	·94431	·9751146
1817	·89552	·9520753	1867	·92016	·9638634	1917	·94480	·9753399
1818	·89601	·9523129	1868	·92065	·9640946	1918	·94529	·9755651
1819	·89651	·9525551	1869	·92115	·9643304	1919	·94579	·9757947
1820	·89699	·9527876	1870	·92164	·9645613	1920	·94628	·9760197
1821	·89748	·9530248	1871	·92213	·9647922	1921	·94677	·9762445
1822	·89798	·9532667	1872	·92263	·9650276	1922	·94727	·9764738
1823	·89847	·9535036	1873	·92312	·9652582	1923	·94776	·9766984
1824	·89896	·9537404	1874	·92361	·9654886	1924	·94825	·9769229
1825	·89945	·9539770	1875	·92410	·9657190	1925	·94874	·9771472
1826	·89995	·9542184	1876	·92460	·9659539	1926	·94924	·9773760
1827	·90044	·9544548	1877	·92509	·9661840	1927	·94973	·9776002
1828	·90093	·9546910	1878	·92558	·9664140	1928	·95022	·9778242
1829	·90143	·9549320	1879	·92608	·9666485	1929	·95072	·9780526
1830	·90192	·9551680	1880	·92656	·9668735	1930	·95121	·9782764
1831	·90241	·9554039	1881	·92705	·9671032	1931	·95170	·9785001
1832	·90291	·9556445	1882	·92755	·9673373	1932	·95220	·9787282
1833	·90340	·9558801	1883	·92804	·9675667	1933	·95269	·9789516
1834	·90389	·9561156	1884	·92853	·9677959	1934	·95318	·9791749
1835	·90438	·9563509	1885	·92902	·9680251	1935	·95367	·9793981
1836	·90488	·9565910	1886	·92952	·9682587	1936	·95417	·9796258
1837	·90537	·9568261	1887	·93001	·9684876	1937	·95466	·9798487
1838	·90586	·9570611	1888	·93050	·9687164	1938	·95515	·9800716
1839	·90636	·9573007	1889	·93100	·9689497	1939	·95565	·9802989
1840	·90685	·9575355	1890	·93149	·9691782	1940	·95614	·9805215
1841	·90734	·9577701	1891	·93198	·9694066	1941	·95663	·9807440
1842	·90784	·9580093	1892	·93248	·9696162	1942	·95713	·9809709
1843	·90833	·9582437	1893	·93297	·9698677	1943	·95762	·9811932
1844	·90882	·9584779	1894	·93346	·9700957	1944	·95811	·9814154
1845	·90931	·9587120	1895	·93395	·9703236	1945	·95860	·9816374
1846	·90981	·9589507	1896	·93445	·9705561	1946	·95910	·9818639
1847	·91030	·9591845	1897	·93494	·9707837	1947	·95959	·9820857
1848	·91079	·9594183	1898	·93543	·9710113	1948	·96008	·9823074
1849	·91129	·9596566	1899	·93593	·9712434	1949	·96058	·9825335
1850	·91178	·9598901	1900	·93642	·9714707	1950	·96106	·9827505

TABLE to convert Yards into Knots—*continued.*

Yards.	Knots.	Log.	Yards.	Knots.	Log.	Yards.	Knots.	Log.
1951	·96155	·9829719	2001	·98620	·9939650	2051	1·01084	·0046652
1952	·96205	·9831976	2002	·98670	·9941851	2052	1·01134	·0048800
1953	·96254	·9834188	2003	·98719	·9944007	2053	1·01183	·0050947
1954	·96303	·9836398	2004	·98768	·9946163	2054	1·01232	·0053092
1955	·96352	·9838607	2005	·98817	·9948317	2055	1·01281	·0055237
1956	·96402	·9840860	2006	·98867	·9950514	2056	1·01331	·0057380
1957	·96451	·9843067	2007	·98916	·9952665	2057	1·01380	·0059523
1958	·96500	·9845273	2008	·98965	·9954816	2058	1·01429	·0061664
1959	·96550	·9847523	2009	·99015	·9957010	2059	1·01479	·0063805
1960	·96599	·9849726	2010	·99064	·9959159	2060	1·01528	·0065944
1961	·96648	·9851929	2011	·99113	·9961306	2061	1·01577	·0068082
1962	·96698	·9854175	2012	·99163	·9963497	2062	1·01627	·0070219
1963	·96747	·9856375	2013	·99212	·9965642	2063	1·01676	·0072355
1964	·96796	·9858574	2014	·99261	·9967786	2064	1·01725	·0074490
1965	·96845	·9860772	2015	·99310	·9969930	2065	1·01774	·0076198
1966	·96895	·9863014	2016	·99360	·9972116	2066	1·01824	·0078331
1967	·96944	·9865209	2017	·99409	·9974257	2067	1·01873	·0080463
1968	·96993	·9867404	2018	·99458	·9976397	2068	1·01922	·0082594
1969	·97043	·9869642	2019	·99508	·9978580	2069	1·01972	·0084724
1970	·97092	·9871834	2020	·99556	·9980674	2070	1·02021	·0086853
1971	·97141	·9874026	2021	·99605	·9982811	2071	1·02070	·0088981
1972	·97191	·9876261	2022	·99655	·9984991	2072	1·02120	·0091108
1973	·97240	·9878450	2023	·99704	·9987126	2073	1·02169	·0093234
1974	·97289	·9880637	2024	·99753	·9989260	2074	1·02218	·0095359
1975	·97338	·9882824	2025	·99802	·9991392	2075	1·02267	·0097483
1976	·97388	·9885054	2026	·99852	·9993568	2076	1·02317	·0099605
1977	·97437	·9887239	2027	·99901	·9995698	2077	1·02366	·0101727
1978	·97486	·9889423	2028	·99950	·9997828	2078	1·02415	·0103848
1979	·97536	·9891649	2029	1·00000	·0000	2079	1·02465	·0105967
1980	·97585	·9893831	2030	1·00049	·0002171	2080	1·02514	·0107662
1981	·97634	·9896011	2031	1·00098	·0004341	2081	1·02563	·0109780
1982	·97684	·9898234	2032	1·00148	·0006510	2082	1·02613	·0111897
1983	·97733	·9900412	2033	1·00197	·0008677	2083	1·02662	·0114013
1984	·97782	·9902589	2034	1·00246	·0010844	2084	1·02711	·0116127
1985	·97831	·9904765	2035	1·00295	·0013009	2085	1·02760	·0118241
1986	·97881	·9906984	2036	1·00345	·0015174	2086	1·02810	·0120354
1987	·97930	·9909158	2037	1·00394	·0016905	2087	1·02859	·0122465
1988	·97979	·9911330	2038	1·00443	·0019067	2088	1·02908	·0124576
1989	·98029	·9913546	2039	1·00493	·0021228	2089	1·02958	·0126685
1990	·98078	·9915716	2040	1·00542	·0023389	2090	1·03006	·0128794
1991	·98127	·9917885	2041	1·00591	·0025548	2091	1·03055	·0130901
1992	·98177	·9920098	2042	1·00641	·0027706	2092	1·03103	·0132587
1993	·98226	·9922265	2043	1·00690	·0029863	2093	1·03154	·0134692
1994	·98275	·9924431	2044	1·00739	·0032019	2094	1·03203	·0136797
1995	·98324	·9926595	2045	1·00788	·0034174	2095	1·03252	·0138901
1996	·98374	·9928803	2046	1·00838	·0036328	2096	1·03302	·0141003
1997	·98423	·9930966	2047	1·00887	·0038481	2097	1·03351	·0143105
1998	·98472	·9933128	2048	1·00936	·0040633	2098	1·03400	·0145205
1999	·98522	·9935332	2049	1·00986	·0042784	2099	1·03450	·0147305
2000	·98571	·9937492	2050	1·01035	·0044933	2100	1·03499	·0149403

TABLE to convert Yards into Knots—*continued.*

Yards.	Knots.	Log.	Yards.	Knots.	Log.	Yards.	Knots.	Log.
2101	1·03548	·0151501	2136	1·05274	·0223046	2171	1·06998	·0293838
2102	1·03598	·0153598	2137	1·05323	·0225109	2172	1·07048	·0295867
2103	1·03647	·0155693	2138	1·05372	·0227170	2173	1·07097	·0297895
2104	1·03696	·0157788	2139	1·05422	·0229230	2174	1·07146	·0299922
2105	1·03745	·0159881	2140	1·05471	·0231289	2175	1·07195	·0301948
2106	1·03795	·0161974	2141	1·05520	·0233348	2176	1·07245	·0303973
2107	1·03844	·0163647	2142	1·05570	·0235405	2177	1·07294	·0305592
2108	1·03893	·0165737	2143	1·05619	·0237462	2178	1·07343	·0307616
2109	1·03943	·0167827	2144	1·05668	·0239517	2179	1·07393	·0309638
2110	1·03992	·0169916	2145	1·05717	·0241572	2180	1·07442	·0311660
2111	1·04041	·0172003	2146	1·05767	·0243625	2181	1·07491	·0313681
2112	1·04091	·0174090	2147	1·05816	·0245678	2182	1·07541	·0315700
2113	1·04140	·0176176	2148	1·05865	·0247729	2183	1·07590	·0317719
2114	1·04189	·0178260	2149	1·05915	·0249780	2184	1·07639	·0319737
2115	1·04238	·0180344	2150	1·05964	·0251419	2185	1·07688	·0321754
2116	1·04288	·0182427	2151	1·06013	·0253468	2186	1·07738	·0323770
2117	1·04337	·0184508	2152	1·06063	·0255516	2187	1·07787	·0325785
2118	1·04386	·0186589	2153	1·06112	·0257563	2188	1·07836	·0327799
2119	1·04436	·0188669	2154	1·06161	·0259609	2189	1·07886	·0329812
2120	1·04485	·0190747	2155	1·06210	·0261654	2190	1·07935	·0331824
2121	1·04534	·0192410	2156	1·06260	·0263698	2191	1·07984	·0333433
2122	1·04584	·0194486	2157	1·06309	·0265741	2192	1·08034	·0335444
2123	1·04633	·0196562	2158	1·06358	·0267783	2193	1·08083	·0337453
2124	1·04682	·0198637	2159	1·06408	·0269824	2194	1·08132	·0339462
2125	1·04731	·0200711	2160	1·06456	·0271865	2195	1·08181	·0341470
2126	1·04781	·0202784	2161	1·06505	·0273904	2196	1·08231	·0343477
2127	1·04830	·0204856	2162	1·06555	·0275942	2197	1·08280	·0345482
2128	1·04879	·0206927	2163	1·06604	·0277572	2198	1·08329	·0347487
2129	1·04929	·0208997	2164	1·06653	·0279609	2199	1·08379	·0349491
2130	1·04978	·0211066	2165	1·06702	·0281644	2200	1·08428	·0351495
2131	1·05027	·0213134	2166	1·06752	·0283679			
2132	1·05077	·0215201	2167	1·06801	·0285713			
2133	1·05126	·0217267	2168	1·06850	·0287745			
2134	1·05175	·0219332	2169	1·06900	·0289777			
2135	1·05224	·0220983	2170	1·06949	·0291808			

The following table shows how many nautical miles answer to a degree of longitude at every degree of latitude.

Lat.	Knots.	Lat.	Knots.	Lat.	Knots.	Lat.	Knots.	Lat.	Knots.
1	59·99	19	56·73	37	47·92	55	34·41	73	17·54
2	59·96	20	56·38	38	47·28	56	33·55	74	16·54
3	59·92	21	56·01	39	46·63	57	32·68	75	15·53
4	59·85	22	55·63	40	45·96	58	31·80	76	14·52
5	59·77	23	55·23	41	45·28	59	30·90	77	13·50
6	59·67	24	54·81	42	45·59	60	30·00	78	12 47
7	59·55	25	54·38	43	43·88	61	29·09	79	11·45
8	59·42	26	53·93	44	43·16	62	28·17	80	10·42
9	59·26	27	53·46	45	42·43	63	27·24	81	9 39
10	59·09	28	52·98	46	41·68	64	26·30	82	8·35
11	58·90	29	52·48	47	40·92	65	25·36	83	7·31
12	58·69	30	51·96	48	40·15	66	24·40	84	6·27
13	58·46	31	51·43	49	39·36	67	23·44	85	5·23
14	58·22	32	50·88	50	38·57	68	22·48	86	4·19
15	57·96	33·	50·32	51	37·76	69	21·50	87	3·14
16	57·68	34	49·74	52	36·94	70	20·52	88	2·09
17	57·38	35	49·15	53	36·11	71	19·53	89	1·05
18	57·06	36	48·54	54	35·27	72	18·54	90	0·00

FRENCH AND ENGLISH MEASURES.

To convert millimetres into inches, multiply by ·03937.

To convert metres* into inches (*or millimetres into mils*), multiply by 39·37.

To convert metres into feet, multiply by 3·281.

To convert metres into yards, multiply by 1·094.

To convert kilometres into statute miles, multiply by ·6214.

To convert kilometres into nautical miles, multiply by ·539.

To convert grammes into grains, multiply by 15·44.

To convert kilogrammes into pounds, multiply by 2·205.

* For the purpose of memory, a metre may be considered as *three feet, three inches, and third.*

English.	French.		
	Linear.	Square.	Cube.
1 mil. =	0·0254 millimètres	0·00064513 millimètres	0·000016386 millimètres
1 inch =	2·5399 centimètres	6·4513 centimètres	16·386 centimètres
1 foot =	3·0480 décimètres	9·2900 décimètres	28·315 décimètres
1 yard =	0·91439 mètres	0·83610 mètres	0·76451 mètres

French.	English.		
	Linear.	Square.	Cube.
1 millimètre =	0·039371 inches	0·0015501 inches	0·000061027 inches
1 centimètre =	0·39371 inches	0·15501 inches	0·061027 inches
1 décimètre =	0·32809 feet	0·10765 feet	0·035317 feet
1 mètre =	1·09363 yards	1·1960 yards	1·3080 yards
do. =	3·2809 feet	10·765 feet	35·317 feet

ENGLISH Miles to Kilomètres.

Miles.	Kilomètres.	Mètres.	Miles.	Kilomètres.	Mètres.	Miles.	Kilomètres.	Mètres.	Miles.	Kilomètres.	Mètres.
1	1	609	26	41	842	51	82	075	76	122	308
2	3	219	27	43	451	52	83	6[illegible]4	77	123	917
3	4	828	28	45	061	53	85	294	78	125	527
4	6	437	29	46	670	54	86	903	79	127	136
5	8	047	30	48	279	55	88	512	80	128	745
6	9	656	31	49	889	56	90	122	81	130	355
7	11	265	32	51	498	57	91	731	82	131	964
8	12	874	33	53	107	58	93	340	83	133	573
9	14	484	34	54	717	59	94	950	84	135	182
10	16	093	35	56	326	60	96	559	85	136	792
11	17	702	36	57	935	61	98	168	86	138	401
12	19	312	37	59	545	62	99	778	87	140	010
13	20	921	38	61	154	63	101	387	88	141	620
14	22	530	39	62	763	64	102	996	89	143	229
15	24	140	40	64	372	65	104	605	90	144	838
16	25	749	41	65	982	66	106	215	91	146	448
17	27	358	42	67	591	67	107	824	92	148	057
18	28	968	43	69	201	68	109	433	93	149	666
19	30	577	44	70	810	69	111	043	94	151	276
20	32	186	45	72	419	70	112	652	95	152	885
21	33	796	46	74	028	71	114	261	96	154	494
22	35	405	47	75	638	72	115	871	97	156	104
23	37	014	48	77	247	73	117	480	98	157	713
24	38	624	49	78	856	74	119	089	99	159	322
25	40	232	50	80	466	75	120	699	100	160	931

TABLE of the Value of French Mètres, from 1 to 100, in English Feet.

Mètres.	English Feet.	Mètres.	English Feet.	Mètres.	English Feet.	Mètres.	English Feet.
1	3·2809	26	85·3013	51	167·3258	76	249·3483
2	6·5618	27	88·5842	52	170·6067	77	252·6292
3	9 8427	28	91·8651	53	173·8876	78	255·9101
4	13·1236	29	95·1460	54	177·1685	79	259·1910
5	16 4045	30	98·4269	55	180·4494	80	262·4719
6	19·6854	31	101·7078	56	183·7303	81	265·7528
7	22·9663	32	104·9887	57	187·0112	82	269·0337
8	26·2472	33	108·2696	58	190·2921	83	272·3146
9	29 5281	34	111·5505	59	193·5730	84	275·5955
10	32 8090	35	114·8314	60	196·8539	85	278·8764
11	36·0898	36	118·1123	61	200·1348	86	282·1573
12	39·3707	37	121·3932	62	201 4157	87	285·4382
13	42·6516	38	124·6741	63	206·6966	88	288·7191
14	45·9325	39	127·9550	64	209·9775	89	292·0000
15	49·2134	40	131·2359	65	213·2584	90	295·2809
16	52·4943	41	134·5168	66	216·5393	91	298·5618
17	55·7752	42	137·7977	67	219·8202	92	301 8427
18	59·0561	43	141·0786	68	223·1011	93	305·1236
19	62·3170	44	144·3595	69	226·3820	94	308 4045
20	65 6180	45	147·6404	70	229·6629	95	311·6854
21	68·8988	46	150·9213	71	232 9438	96	314·9663
22	72·1797	47	154·2022	72	236·2247	97	318·2472
23	75·4606	48	157·4831	73	239·5056	98	321·5281
24	78 7415	49	160·7640	74	242·7865	99	324·8090
25	82 0224	50	164·0449	75	246·0674	100	328·0899

CENTIMÈTRES and Millimètres to Inches.

Centi-mètres.	Millimètres.									
	0	1	2	3	4	5	6	7	8	9
	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.
0		0·04	0·08	0·12	0·16	0·20	0·24	0·28	0·31	0·35
1	0·39	0·43	0·47	0 51	0·55	0·59	0·63	0 67	0·71	0·75
2	0·79	0 83	0·87	0·91	0·94	0·98	1·02	1·06	1·10	1·14
3	1·18	1·22	1·26	1·30	1·34	1·38	1·42	1·46	1·50	1·54
4	1·57	1·61	1·65	1·69	1·73	1·77	1·81	1·85	1·89	1·93
5	1·97	2·01	2·05	2·09	2·13	2·17	2·20	2·24	2·83	2·32
6	2·36	2·40	2·44	2·48	2·52	2·56	2·60	2·64	2·63	2·72
7	2·76	2·80	2·83	2·87	2·91	2·95	2·99	2·03	3·07	3·11
8	3 15	3·19	3·23	3·27	3·31	3·35	3·39	3·43	3·47	3·50
9	3·54	3·58	3·62	3·66	3·70	3·74	3·78	3·82	3·86	3·90
10	3·94	3·98	4·02	4·06	4·09	4·13	4·17	4·21	4·25	4·29
	0	1	2	3	4	5	6	7	8	9

To convert Avoirdupois pounds per lineal yard into kilogrammes per lineal metre, multiply by 0·496. To convert kilogrammes per metre to lbs. per yard, multiply by 2·02.

TABLE of the Value of French Kilogrammes, in Pounds Avoirdupois.

Kilo-grms.	lbs. Avoirdupois.	Kilo-grms.	lbs. Avoirdupois.	Kilo-grms.	lbs. Avoirdupois.	Kilo-grms.	lbs. Avoirdupois.
1	2·2060	14	30·8848	27	59·5635	40	88·2424
2	4·4121	15	33·0908	28	61·7696	41	90·4484
3	6·6182	16	35·2969	29	63·9757	42	92·6545
4	8·8242	17	37·5029	30	66·1818	43	94·8605
5	11·0303	18	39·7090	31	68·3878	44	97·0666
6	13·2364	19	41·9150	32	70·5939	45	99·2726
7	15·4424	20	44·1212	33	72·7999	46	101·4787
8	17·6485	21	46·3272	34	75·0060	47	103·6847
9	19·8545	22	48·5333	35	77·2120	48	105·8908
10	22·0606	23	50·7393	36	79·4181	49	108·0969
11	24·2666	24	52·9454	37	81·6241	50	110·3030
12	26·4727	25	55·1514	38	83·8302	51	112·5090
13	28·6787	26	57·3575	39	86·0363	52	114·7151

TRIGONOMETRICAL FORMULÆ.

1 *Sinus*	abbreviated	*sin.C.*
2 *Cosinus*	,,	*cos.C.*
3 *Sinus-versus*	,,	*sinv.C.*
4 *Cosinus-versus*	,,	*cosv.C.*
5 *Tangent*	,,	*tan.C.*
6 *Cotangent*	,,	*cot.C.*
7 *Secant*	,,	*sec.C.*
8 *Cosecant*	,,	*cosec.C.*

r = *Radius* of the circle, which is the unit by which the functions are measured.

$$r^2 = \sin^2 C + \cos^2 C,$$

$$\tan C = \frac{\sin C}{\cos C},$$

$$\tan C = \frac{1}{\cot C},$$

$$\cot C = \frac{\cos C}{\sin C},$$

$$\cot C = \frac{1}{\tan C},$$

$$\sec C = \frac{1}{\cos C},$$

$$\operatorname{cosec} C = \frac{1}{\sin C},$$

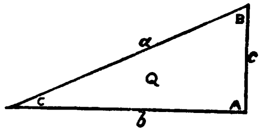
$$\operatorname{sinv} C = 1 - \cos C,$$

$$\operatorname{cosv} C = 1 \sin C,$$

$$\sin 2C = 2 \sin C \cos C,$$

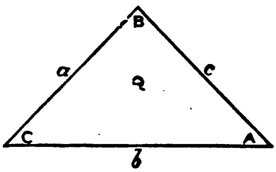
$$\sin \tfrac{1}{2}C = \tfrac{1}{2}\sqrt{(\sin^2 C + \operatorname{sinv}^2 C)},$$

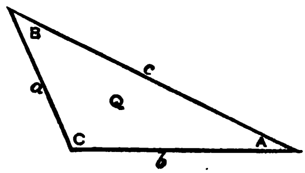
$$\sin (C \pm B) = \sin C \cos B \pm \sin B \cos C.$$



A, B, C, angles.
a, *b*, *c*, sides.
Q, area.

1. $a = \sqrt{b^2 + c^2}$,
2. $a = \dfrac{c}{\sin C}$,
3. $a = \dfrac{b}{\cos C}$,
4. $a = 2\sqrt{\dfrac{Q}{\sin 2C}}$,
5. $b = a \cos C$,
6. $b = c \cot C$,
7. $b = a \sin B$,
8. $b = c \tan B$,
9. $b = \sqrt[2]{\dfrac{2Q}{\tan C}}$,





$a : b = \sin A : \sin B$, and $b : c = \sin B : \sin C$
$a : c = \sin A : \sin C$, and $Q : ab = \sin C : 2$.

1. $a = \dfrac{c \sin A}{\sin C}$,
2. $a = \dfrac{c \sin A}{\sin (A + B)}$,
3. $a = \dfrac{2Q}{b \sin C}$,
4. $b = \dfrac{c \sin B}{\sin C}$,
5. $b = \dfrac{2Q}{c \sin A}$,
6. $a = \sqrt{b^2 + c^2 - 2bc \cos A}$,
7. $a = \sqrt{\dfrac{2Q \sin A}{\sin B \sin (A + B)}}$,

MEASURE OF THE CIRCLE.

seconds (″)
60 = 1 *minute* (′)
3600 = 60 = 1 *degree* (°)
324000 = 5400 = 90 = 1 *quadrant*
1296000 = 21600 = 360 = 4 = 1 *circumference*

Natural Sines ($r = 1$) of whole degrees and decimal parts, from 1°·0 to 90°·0 inclusive.

Deg.	0	·1	·2	·3	·4	·5	·6	·7	·8	·9	·0	
0	·0000	·0017	·0035	·0052	·0070	·0087	·0105	·0122	·0140	·0157	·0175	89
1	·0175	·0192	·0209	·0227	·0244	·0262	·0279	·0297	·0314	·0332	·0349	88
2	·0349	·0366	·0384	·0401	·0419	·0436	·0454	·0471	·0488	·0506	·0523	87
3	·0523	·0541	·0558	·0576	·0593	·0610	·0628	·0645	·0663	·0680	·0698	86
4	·0698	·0715	·0732	·0750	·0767	·0785	·0802	·0819	·0837	·0854	·0872	85
5	·0872	·0889	·0906	·0924	·0941	·0958	·0976	·0993	·1011	·1028	·1045	84
6	·1045	·1063	·1080	·1097	·1115	·1132	·1149	·1167	·1184	·1201	·1219	83
7	·1219	·1236	·1253	·1271	·1288	·1305	·1323	·1340	·1357	·1374	·1392	82
8	·1392	·1409	·1426	·1444	·1461	·1478	·1495	·1513	·1530	·1547	·1564	81
9	·1564	·1582	·1599	·1616	·1633	·1650	·1668	·1685	·1702	·1719	·1736	80
10	·1736	·1754	·1771	·1788	·1805	·1822	·1840	·1857	·1874	·1891	·1908	79
11	·1908	·1925	·1942	·1959	·1977	·1994	·2011	·2028	·2045	·2062	·2079	78
12	·2079	·2096	·2113	·2130	·2147	·2164	·2181	·2198	·2215	·2233	·2250	77
13	·2250	·2267	·2284	·2300	·2317	·2334	·2351	·2368	·2385	·2402	·2419	76
14	·2419	·2436	·2453	·2470	·2487	·2504	·2521	·2538	·2554	·2571	·2588	75
15	·2588	·2605	·2622	·2639	·2656	·2672	·2689	·2706	·2723	·2740	·2756	74
16	·2756	·2773	·2790	·2807	·2823	·2840	·2857	·2874	·2890	·2907	·2924	73
17	·2924	·2940	·2957	·2974	·2990	·3007	·3024	·3040	·3057	·3074	·3090	72
18	·3090	·3107	·3123	·3140	·3156	·3173	·3190	·3206	·3223	·3239	·3256	71
19	·3256	·3272	·3289	·3305	·3322	·3338	·3355	·3371	·3387	·3404	·3420	70
20	·3420	·3437	·3453	·3469	·3486	·3502	·3518	·3535	·3551	·3567	·3584	69
21	·3584	·3600	·3616	·3633	·3649	·3665	·3681	·3697	·3714	·3730	·3746	68
22	·3746	·3762	·3778	·3795	·3811	·3827	·3843	·3859	·3875	·3891	·3907	67
23	·3907	·3923	·3939	·3955	·3971	·3987	·4003	·4019	·4035	·4051	·4067	66
24	·4067	·4083	·4099	·4115	·4131	·4147	·4163	·4179	·4195	·4210	·4226	65
25	·4226	·4242	·4258	·4274	·4289	·4305	·4321	·4337	·4352	·4368	·4384	64
26	·4384	·4399	·4415	·4431	·4446	·4462	·4478	·4493	·4509	·4524	·4540	63
27	·4540	·4555	·4571	·4586	·4602	·4617	·4633	·4648	·4664	·4679	·4695	62
28	·4695	·4710	·4726	·4741	·4756	·4772	·4787	·4802	·4818	·4833	·4848	61
29	·4848	·4863	·4879	·4894	·4909	·4924	·4939	·4955	·4970	·4985	·5000	60
30	·5000	·5015	·5030	·5045	·5060	·5075	·5090	·5105	·5120	·5135	·5150	59
31	·5150	·5165	·5180	·5195	·5210	·5225	·5240	·5255	·5270	·5284	·5299	58
32	·5299	·5314	·5329	·5344	·5358	·5373	·5388	·5402	·5417	·5432	·5446	57
33	·5446	·5461	·5476	·5490	·5505	·5519	·5534	·5548	·5563	·5577	·5592	56
34	·5592	·5606	·5621	·5635	·5650	·5664	·5678	·5693	·5707	·5721	·5736	55
35	·5736	·5750	·5764	·5779	·5793	·5807	·5821	·5835	·5850	·5864	·5878	54
36	·5878	·5892	·5906	·5920	·5934	·5948	·5962	·5976	·5990	·6004	·6018	53
37	·6018	·6032	·6046	·6060	·6074	·6088	·6101	·6115	·6129	·6143	·6157	52
38	·6157	·6170	·6184	·6198	·6211	·6225	·6239	·6252	·6266	·6280	·6293	51
39	·6293	·6307	·6320	·6334	·6347	·6361	·6374	·6388	·6401	·6414	·6428	50
40	·6428	·6441	·6455	·6468	·6481	·6494	·6508	·6521	·6534	·6547	·6561	49
41	·6561	·6574	·6587	·6600	·6613	·6626	·6639	·6652	·6665	·6678	·6691	48
42	·6691	·6704	·6717	·6730	·6743	·6756	·6769	·6782	·6794	·6807	·6820	47
43	·6820	·6833	·6845	·6858	·6871	·6884	·6896	·6909	·6921	·6934	·6947	46
44	·6947	·6959	·6972	·6984	·6997	·7009	·7022	·7034	·7046	·7059	·7071	45
	1·0	·9	·8	·7	·6	·5	·4	·3	·2	·1	·0	Deg.

Natural Cosines ($r = 1$).

Natural Sines ($r = 1$).

Deg.	0	·1	·2	·3	·4	·5	·6	·7	·8	·9	·0	
45	·7071	·7083	·7096	·7108	·7120	·7133	·7145	·7157	·7169	·7181	·7193	44
46	·7193	·7206	·7218	·7230	·7242	·7254	·7266	·7278	·7290	·7302	·7314	43
47	·7314	·7325	·7337	·7349	·7361	·7373	·7385	·7396	·7408	·7420	·7431	42
48	·7431	·7343	·7455	·7366	·7478	·7490	·7501	·7513	·7424	·7536	·7547	41
49	·7547	·7459	·7570	·7481	·7593	·7604	·7615	·7627	·7638	·7649	·7660	40
50	·7660	·7672	·7683	·7694	·7705	·7716	·7727	·7738	·7749	·7760	·7771	39
51	·7771	·7782	·7793	·7804	·7815	·7826	·7837	·7848	·7859	·7869	·7880	38
52	·7880	·7891	·7902	·7912	·7923	·7934	·7944	·7955	·7965	·7976	·7986	37
53	·7986	·7997	·8007	·8018	·8028	·8039	·8049	·8059	·8070	·7080	·8090	36
54	·8090	·8100	·8111	·8121	·8131	·8141	·8151	·8161	·8171	·8181	·8192	35
55	·8192	·8202	·8211	·8221	·8231	·8241	·8251	·8261	·8271	·8281	·8290	34
56	·8290	·8300	·8310	·8320	·8329	·8339	·8348	·8358	·8368	·8377	·8387	33
57	·8387	·8396	·8406	·8415	·8425	·8434	·8443	·8453	·8462	·8471	·8480	32
58	·8480	·8490	·8499	·8508	·8517	·8526	·8536	·8545	·8554	·8563	·8572	31
59	·8572	·8581	·8590	·8599	·8607	·8616	·8625	·8634	·8643	·8652	·8660	30
60	·8660	·8669	·8678	·8686	·8695	·8704	·8712	·8721	·8729	·8738	·8746	29
61	·8746	·8755	·8763	·8771	·8780	·8788	·8796	·8805	·8813	·8821	·8829	28
62	·8829	·8838	·8846	·8854	·8862	·8870	·8878	·8886	·8894	·8902	·8910	27
63	·8910	·8918	·8926	·8934	·8942	·8949	·8957	·8965	·8973	·8980	·8988	26
64	·8988	·8996	·9003	·9011	·9018	·9026	·9033	·9041	·9048	·9056	·9063	25
65	·9063	·9070	·9078	·9085	·9092	·9100	·9107	·9114	·9121	·9128	·9135	24
66	·9135	·9143	·9150	·9157	·9164	·9171	·9178	·9184	·9191	·9198	·9205	23
67	·9205	·9212	9219	·9225	·9232	·9239	·9245	·9252	·9259	·9265	·9272	22
68	·9272	·9278	·9285	·9291	·9298	·9304	·9311	·9317	·9323	·9330	·9336	21
69	·9336	·9342	·9348	·9354	·9361	·9367	·9373	·9379	·9385	·9391	·9397	20
70	·9397	·9403	·9409	·9415	·9421	·9426	·9432	·9438	·9444	·9449	·9455	19
71	·9455	·9461	·9466	·9472	·9478	·9483	·9489	·9494	·9500	·9505	·9511	18
72	·9511	·9516	9521	·9527	·9532	·9537	·9542	·9548	·9553	·9558	·9563	17
73	·9563	·9568	·9573	·9578	·9583	·9588	·9593	·9598	·9603	·9608	·9613	16
74	·9613	·9617	·9622	·9627	·9632	·9636	·9641	·9646	·9650	·9655	·9659	15
75	·9659	·9664	·9668	·9673	·9677	·9681	·9686	·9690	·9694	·9699	·9703	14
76	·9703	·9707	·9711	·9715	·9720	9724	·9728	·9732	·9736	·9740	·9744	13
77	·9744	·9748	·9751	·9755	9759	·9763	·9767	·9770	·9774	·9778	·9781	12
78	·9781	·9785	·9789	·9792	·9796	·9799	·9803	·9806	·9810	·9813	·9816	11
79	·9816	·9820	·9823	·9826	·9829	·9833	·9836	·9839	·9842	·9845	·9848	10
80	·9848	·9851	·9854	·9857	·9860	·9863	·9866	·9869	·9871	·9874	·9877	9
81	·9877	·9880	·9882	·9885	·9888	·9890	·9893	·9895	·9898	·9900	·9903	8
82	·9903	·9905	·9907	·9910	·9912	·9914	·9917	·9919	·9921	·9923	·9925	7
83	·9925	·9928	·9930	·9932	·9934	·9936	·9938	·9940	·9942	·9943	·9945	6
84	·9945	·9947	·9949	·9951	·9952	·9954	·9956	·9957	·9959	·9960	·9962	5
85	·9962	·9963	·9965	·9966	·9968	·9969	·9971	·9972	·9973	·9974	·9976	4
86	·9976	·9977	·9978	·9979	·9980	·9981	·9982	·9983	·9984	·9985	·9986	3
87	·9986	·9987	·9988	·9989	·9990	·9990	·9991	·9992	·9993	·9993	·9994	2
88	·9994	·9995	·9995	·9996	·9996	·9997	·9997	·9997	·9998	·9998	·9998	1
89	·9998	·9999	·9999	·9999	·9999	1·000	1·000	1·000	1·000	1·000	1·000	0
	1·0	·9	·8	·7	·6	·5	·4	·3	·2	·1	·0	Deg.

Natural Cosines ($r = 1$).

Natural Tangents ($r = 1$) of whole degrees and decimal parts, from 1°·0 to 90°·0.

Deg.	0	·1	·2	·3	·4	·5	·6	·7	·8	·9	1·0	
0	·0000	·0017	·0035	·0052	·0070	·0087	·0105	·0122	·0140	·0157	·0175	89
1	·0175	·0192	·0209	·0227	·0244	·0262	·0279	·0297	·0314	·0332	·0349	88
2	·0349	·0367	·0384	·0402	·0419	·0437	·0454	·0472	·0489	·0507	·0524	87
3	·0524	·0542	·0559	·0577	·0594	·0612	·0629	·0647	·0664	·0682	·0699	86
4	·0699	·0717	·0734	·0752	·0769	·0787	·0805	·0822	·0840	·0857	·0875	85
5	·0875	·0892	·0910	·0928	·0945	·0963	·0981	·0998	·1016	·1033	·1051	84
6	·1051	·1069	·1086	·1104	·1122	·1139	·1157	·1175	·1192	·1210	·1228	83
7	·1228	·1246	·1263	·1281	·1299	·1317	·1334	·1352	·1370	·1388	·1405	82
8	·1405	·1423	·1441	·1459	·1477	·1495	·1512	·1530	·1548	·1566	1584	81
9	·1584	·1602	·1620	·1638	·1655	·1673	·1691	·1709	·1727	·1745	·1763	80
10	·1763	·1781	·1799	·1817	·1835	·1853	·1871	·1890	·1908	·1926	·1944	79
11	·1944	·1962	·1980	·1998	·2016	·2035	·2053	·2071	·2089	·2107	·2126	78
12	·2126	·2144	·2162	·2180	·2199	·2217	·2235	·2254	·2272	·2290	·2309	77
13	·2309	·2327	·2345	·2364	·2382	·2401	·2419	·2438	·2456	·2475	·2493	76
14	·2493	·2512	·2530	·2549	·2568	·2586	·2605	·2623	·2642	·2661	·2679	75
15	·2679	·2698	·2717	·2736	·2754	·2773	·2792	·2811	·2830	·2849	·2867	74
16	·2867	·2886	·2905	·2924	·2943	·2962	·2981	·3000	·3019	·3038	·3057	73
17	·3057	·3076	·3096	·3115	·3134	·3153	·3172	·3191	·3211	·3230	·3249	72
18	·3249	·3269	·3288	·3307	·3327	·3346	·3365	·3385	·3404	·3424	·3443	71
19	·3443	·3463	·3482	·3502	·3522	·3541	·3561	·3581	·3600	·3620	·3640	70
20	·3640	·3659	·3679	·3699	·3719	·3739	·3759	·3779	·3799	·3819	·3839	69
21	·3839	·3859	·3879	·3899	·3919	·3939	·3959	·3979	·4000	·4020	·4040	68
22	·4040	·4061	·4081	·4101	·4122	·4142	·4163	·4183	·4204	·4224	·4245	67
23	·4245	·4265	·4286	·4307	·4327	·4348	·4369	·4390	·4411	·4431	·4452	66
24	·4452	·4473	·4494	·4515	·4536	·4557	·4578	·4599	·4621	·4042	·4663	65
25	·4663	·4684	·4706	·4727	·4748	·4770	·4791	·4813	·4834	·4856	·4877	64
26	·4877	·4899	·4921	·4942	·4964	·4986	·5008	·5029	·5051	·5073	·5095	63
27	·5095	·5117	·5139	·5161	·5184	·5206	·5228	·5250	·5272	·5295	·5317	62
28	·5317	·5340	·5362	·5384	·5407	·5430	·5452	·5475	·5498	·5520	·5543	61
29	·5543	·5566	·5589	·5612	·5635	·5658	·5681	·5704	·5727	·5750	·5774	60
30	·5774	·5797	·5820	·5844	·5867	·5890	·5914	·5938	·5961	·5985	·6009	59
31	·6009	·6032	·6056	·6080	·6104	·6128	·6152	·6176	·6200	·6224	·6249	58
32	·6249	·6273	·6297	·6322	·6346	·6371	·6395	·6420	·6445	·6469	·6494	57
33	·6494	·6519	·6544	·6569	·6594	·6619	·6644	·6669	·6694	·6720	·6745	56
34	·6745	·6771	·6796	·6822	·6847	·6873	·6899	·6924	·6950	·6976	·7002	55
35	·7002	·7028	·7054	·7080	·7107	·7133	·7159	·7186	·7212	·7239	·7265	54
36	·7265	·7292	·7319	·7346	·7373	·7400	·7427	·7454	·7481	·7508	·7536	53
37	·7536	·7563	·7590	·7618	·7646	·7673	·7701	·7729	·7757	·7785	·7813	52
38	·7813	·7841	·7869	·7898	·7926	·7954	·7983	·8012	·8040	·8069	·8098	51
39	·8098	·8127	·8156	·8185	·8214	·8243	·8273	·8302	·8332	·8361	·8391	50
40	·8391	·8421	8451	·8481	·8511	·8541	·8571	·8601	·8632	·8662	·8693	49
41	·8693	·8724	·8754	·8785	·8816	·8847	·8878	·8910	·8941	·8972	·9004	48
42	·9004	·9036	·9067	·9099	·9131	·9163	·9195	·9228	·9260	·9293	·9325	47
43	·9325	·9358	·0391	·9424	·9457	·9490	·9523	·9556	·9590	·9623	·9657	46
44	·9657	·9691	·9725	·9759	9793	·9827	·9861	·9896	·9930	·9965	1·000	45
	1·0	·9	·8	·7	·6	·5	·4	·3	·2	·1	·0	Deg.

Natural Cotangents ($r = 1$).

Natural Tangents ($r = 1$)—*continued.*

Deg.	0	·1	·2	·3	·4	·5	·6	·7	·8	·9	·0	
45	1·000	1·003	1·007	1·011	1·014	1·018	1·021	1·025	1·028	1·032	1·036	44
46	1·036	1·039	1·043	1·046	1·050	1·054	1·057	1·061	1·065	1·069	1·072	43
47	1·072	1·076	1·080	1·084	1·087	1·091	1·095	1·099	1·103	1·107	1·111	42
48	1·111	1·115	1·118	1·122	1·126	1·130	1·134	1·138	1·142	1·146	1·150	41
49	1·150	1·154	1·159	1·163	1·167	1·171	1·175	1·179	1·183	1·188	1·192	40
50	1·192	1·196	1·200	1·205	1·209	1·213	1·217	1·222	1·226	1·230	1·235	39
51	1·235	1·239	1·244	1·248	1·253	1·257	1·262	1·266	1·271	1·275	1·280	38
52	1·280	1·285	1·289	1·294	1·299	1·303	1·308	1·313	1·317	1·322	1·327	37
53	1·327	1·332	1·337	1·342	1·347	1·351	1·356	1·361	1·366	1·371	1·376	36
54	1·376	1·381	1·387	1·392	1·397	1·402	1·407	1·412	1·418	1·423	1·428	35
55	1·428	1·433	1·439	1·444	1·450	1·455	1·460	1·466	1·471	1·477	1·483	34
56	1·483	1·488	1·494	1·499	1·505	1·511	1·517	1·522	1·528	1·534	1·540	33
57	1·540	1·546	1·552	1·558	1·564	1·570	1·576	1·582	1·588	1·594	1·600	32
58	1·600	1·607	1·613	1·619	1·625	1·632	1·638	1·645	1·651	1·658	1·664	31
59	1·664	1·671	1·678	1·684	1·691	1·698	1·704	1·711	1·718	1·725	1·732	30
60	1·732	1·739	1·746	1·753	1·760	1·767	1·775	1·782	1·789	1·797	1·804	29
61	1·804	1·311	1·819	1·827	1·834	1·842	1·849	1·857	1·865	1·873	1·881	28
62	1·881	1·889	1·897	1·905	1·913	1·921	1·929	1·937	1·946	1·954	1·963	27
63	1·963	1·971	1·980	1·988	1·997	2·006	2·014	2·023	2·032	2·041	2·050	26
64	2·050	2·059	2·069	2·078	2·087	2·097	2·106	2·116	2·125	2·135	2·145	25
65	2·145	2·154	2·164	2·174	2·184	2·194	2·204	2·215	2·225	2·236	2·246	24
66	2·246	2·257	2·267	2·278	2·289	2·300	2·311	2·322	2·333	2·344	2·356	23
67	2·356	2·367	2·379	2·391	2·402	2·414	2·426	2·438	2·450	2·463	2·475	22
68	2·475	2·488	2·500	2·513	2·526	2·539	2·552	2·565	2·578	2·592	2·605	21
69	2·605	2·619	2·633	2·646	2·660	2·675	2·689	2·703	2·718	2·733	2·747	20
70	2·747	2·762	2·778	2·793	2·808	2·824	2·840	2·856	2·872	2·888	2·904	19
71	2·904	2·921	2·937	2·954	2·971	2·989	3·006	3·024	3·042	3·060	3·078	18
72	3·078	3·096	3·115	3·133	3·152	3·172	3·191	3·211	3·230	3·251	3·271	17
73	3·271	3·291	3·312	3·333	3·354	3·376	3·398	3·420	3·442	3·465	3·487	16
74	3·487	3·511	3·534	3·558	3·582	3·606	3·630	3·655	3·681	3·706	3·732	15
75	3·732	3·758	3·785	3·812	3·839	3·867	3·895	3·923	3·952	3·981	4·011	14
76	4·011	4·041	4·071	4·102	4·134	4·165	4·198	4·230	4·264	4·297	4·331	13
77	4·331	4·366	4·402	4·437	4·474	4·511	4·548	4·586	4·625	4·665	4·705	12
78	4·705	4·745	4·787	4·829	4·872	4·915	4·959	5·005	5·050	5·097	5·145	11
79	5·145	5·193	5·242	5·292	5·343	5·396	5·449	5·503	5·558	5·614	5·671	10
80	5·671	5·730	5·789	5·850	5·912	5·976	6·041	6·107	6·174	6·243	6·314	9
81	6·314	6·386	6·460	6·535	6·612	6·691	6·772	6·855	6·940	7·026	7·115	8
82	7·115	7·207	7·300	7·396	7·495	7·596	7·700	7·806	7·916	8·028	8·144	7
83	8·144	8·264	8·386	8·513	8·643	8·777	8·915	9·058	9·205	9·357	9·514	6
84	9·514	9·677	9·845	10·02	10·20	10·39	10·58	10·78	10·99	11·20	11·43	5
85	11·43	11·66	11·91	12·16	12·43	12·71	13·00	13·30	13·62	13·95	14·30	4
86	14·30	14·67	15·06	15·46	15·89	16·35	16·83	17·34	17·89	18·46	19·08	3
87	19·08	19·74	20·45	21·20	22·02	22·90	23·86	24·90	26·03	27·27	28·64	2
88	28·64	30·14	31·82	33·69	35·80	38·19	40·92	44·07	47·74	52·08	57·29	1
89	57·29	63·66	71·62	81·85	95·49	114·6	143·2	191·0	286·5	573·0	∞	0
	1·0	·9	·8	·7	·6	·5	·4	·3	·2	·1	·0	Deg.

Natural Cotangents ($r = 1$).

TABLE of Squares of Diameters, for finding the value of d^2 and $\sqrt{d}$.

No.	Square.	No.	Square.	No.	Square.	No.	Square.	No.	Square.
1	1	51	2601	101	10201	151	22801	201	40401
2	4	52	2704	102	10404	152	23104	202	40804
3	9	53	2809	103	10609	153	23409	203	41209
4	16	54	2916	104	10816	154	23716	204	41616
5	25	55	3025	105	11025	155	24025	205	42025
6	36	56	3136	106	11236	156	24336	206	42436
7	49	57	3249	107	11449	157	24649	207	42849
8	64	58	3364	108	11664	158	24964	208	43264
9	81	59	3481	109	11881	159	25281	209	43681
10	100	60	3600	110	12100	160	25600	210	44100
11	121	61	3721	111	12321	161	25921	211	44521
12	144	62	3844	112	12544	162	26244	212	44944
13	169	63	3969	113	12769	163	26569	213	45369
14	196	64	4096	114	12996	164	26896	214	45796
15	225	65	4225	115	13225	165	27225	215	46225
16	256	66	4356	116	13456	166	27556	216	46656
17	289	67	4489	117	13689	167	27889	217	47089
18	324	68	4624	118	13924	168	28224	218	47524
19	361	69	4761	119	14161	169	28561	219	47961
20	400	70	4900	120	14400	170	28900	220	48400
21	441	71	5041	121	14641	171	29241	221	48841
22	484	72	5184	122	14884	172	29584	222	49284
23	529	73	5329	123	15129	173	29929	223	49729
24	576	74	5476	124	15376	174	30276	224	50176
25	625	75	5625	125	15625	175	30625	225	50625
26	676	76	5776	126	15876	176	30976	226	51076
27	729	77	5929	127	16129	177	31329	227	51529
28	784	78	6084	128	16384	178	31684	228	51984
29	841	79	6241	129	16641	179	32041	229	52441
30	900	80	6400	130	16900	180	32400	230	52900
31	961	81	6561	131	17161	181	32761	231	53361
32	1024	82	6724	132	17424	182	33124	232	53824
33	1089	83	6889	133	17689	183	33489	233	54289
34	1156	84	7056	134	17956	184	33856	234	54756
35	1225	85	7225	135	18225	185	34225	235	55225
36	1296	86	7396	136	18496	186	34596	236	55696
37	1369	87	7569	137	18769	187	34969	237	56169
38	1444	88	7744	138	19044	188	35344	238	56644
39	1521	89	7921	139	19321	189	35721	239	57121
40	1600	90	8100	140	19600	190	36100	240	57600
41	1681	91	8281	141	19881	191	36481	241	58081
42	1764	92	8464	142	20164	192	36864	242	58564
43	1849	93	8649	143	20449	193	37249	243	59049
44	1936	94	8836	144	20736	194	37636	244	59536
45	2025	95	9025	145	21025	195	38025	245	60025
46	2116	96	9216	146	21316	196	38416	246	60516
47	2209	97	9409	147	21609	197	38809	247	61009
48	2304	98	9604	148	21904	198	39204	248	61504
49	2401	99	9801	149	22201	199	39601	249	62001
50	2500	100	10000	150	22500	200	40000	250	62500

TABLE of Squares of Diameters—*continued.*

No.	Square.	No.	Square.	No.	Square.	No.	Square.	No.	Square.
251	63001	301	90601	351	123201	401	160801	451	203401
252	63504	302	91204	352	123904	402	161604	452	204304
253	64009	303	91809	353	124609	403	162409	453	205209
254	64516	304	92416	354	125316	404	163216	454	206116
255	65025	305	93025	355	126025	405	164025	455	207025
256	65536	306	93636	356	126736	406	164836	456	207936
257	66049	307	94249	357	127449	407	165649	457	208849
258	66564	308	94864	358	128164	408	166464	458	209764
259	67081	309	95481	359	128881	409	167281	459	210681
260	67600	310	96100	360	129600	410	168100	460	211600
261	68121	311	96721	361	130321	411	168921	461	212521
262	68644	312	97344	362	131044	412	169744	462	213444
263	69169	313	97969	363	131769	413	170569	463	214369
264	69696	314	98596	364	132496	414	171396	464	215296
265	70225	315	99225	365	133225	415	172225	465	216225
266	70756	316	99856	366	133956	416	173056	466	217156
267	71289	317	100489	367	134689	417	173889	467	218089
268	71824	318	101124	368	135424	418	174724	468	219024
269	72361	319	101761	369	136161	419	175561	469	219961
270	72900	320	102400	370	136900	420	176400	470	220900
271	73441	321	103041	371	137641	421	177241	471	221841
272	73984	322	103684	372	138384	422	178084	472	222784
273	74529	323	104329	373	139129	423	178929	473	223729
274	75076	324	104976	374	139876	424	179776	474	224676
275	75625	325	105625	375	140625	425	180625	475	225625
276	76176	326	106276	376	141376	426	181476	476	226576
277	76729	327	106929	377	142129	427	182329	477	227529
278	77284	328	107584	378	142884	428	183184	478	228484
279	77841	329	108241	379	143641	429	184041	479	229441
280	78400	330	108900	380	144400	430	184900	480	230400
281	78961	331	109561	381	145161	431	185761	481	231361
282	79524	332	110224	382	145924	432	186624	482	232324
283	80089	333	110889	383	146689	433	187489	483	233289
284	80656	334	111556	384	147456	434	188356	484	234256
285	81225	335	112225	385	148225	435	189225	485	235225
286	81796	336	112896	386	148996	436	190096	486	236196
287	82369	337	113569	387	149769	437	190969	487	237169
288	82944	338	114244	388	150544	438	191844	488	238144
289	83521	339	114921	389	151321	439	192721	489	239121
290	84100	340	115600	390	152100	440	193600	490	240100
291	84681	341	116281	391	152881	441	194481	491	241081
292	85264	342	116964	392	153664	442	195364	492	242064
293	85849	343	117649	393	154449	443	196249	493	243049
294	86436	344	118336	394	155236	444	197136	494	244036
295	87025	345	119025	395	156025	445	198025	495	245025
296	87616	346	119716	396	156816	446	198916	496	246016
297	88209	347	120409	397	157609	447	199809	497	247009
298	88804	348	121104	398	158404	448	200704	498	248004
299	89401	349	121801	399	159201	449	201601	499	249001
300	90000	350	122500	400	160000	450	202500	500	250000

TABLE of Squares of Diameters—*continued.*

No.	Square.	No.	Square.	No.	Square.	No.	Square.	No.	Square.
501	251001	551	303601	601	361201	651	423801	701	491401
502	252004	552	304704	602	362404	652	425104	702	492804
503	253009	553	305809	603	363609	653	426409	703	494209
504	254016	554	306916	604	364816	654	427716	704	495616
505	255025	555	308025	605	366025	655	429025	705	497025
506	256036	556	309136	606	367236	656	430336	706	498436
507	257049	557	310249	607	368449	657	431639	707	499849
508	258064	558	311364	608	369664	658	432964	708	501264
509	259081	559	312481	609	370881	659	434281	709	502681
510	260100	560	313600	610	372100	660	435600	710	504100
511	261121	561	314721	611	373321	661	436921	711	505521
512	262144	562	315844	612	374544	662	438244	712	506944
513	263169	563	316969	613	375769	663	439569	713	508369
514	264196	564	318096	614	376996	664	440896	714	509796
515	265225	565	319225	615	378225	665	442225	715	511225
516	266256	566	320356	616	379456	666	443556	716	512656
517	267289	567	321489	617	380689	667	444899	717	514089
518	268324	568	322624	618	381924	668	446224	718	515524
519	269361	569	323761	619	383161	669	447561	719	516961
520	270400	570	324900	620	384400	670	448900	720	518400
521	271411	571	326041	621	385641	671	450241	721	519841
522	272484	572	327184	622	386884	672	451584	722	521284
523	273529	573	328329	623	388129	673	452929	723	522729
524	274576	574	329476	624	389376	674	454276	724	524176
525	275625	575	330625	625	390625	675	455625	725	525625
526	276676	576	331776	626	391876	676	456976	726	527076
527	277729	577	332927	627	393129	677	458329	727	528529
528	278784	578	334084	628	394384	678	459684	728	529984
529	279841	579	335241	629	395641	679	461041	729	531441
530	280900	580	336400	630	396900	680	462400	730	532900
531	281961	581	337561	631	398161	681	463761	731	534361
532	283024	582	338724	632	399424	682	465124	732	535824
533	284089	583	339889	633	400689	683	466489	733	537289
534	285156	584	341056	634	401956	684	467856	734	538756
535	286225	585	342225	635	403225	685	469225	735	540225
536	287296	586	343396	636	404496	686	470596	736	541696
537	288369	587	344569	637	405769	687	471969	737	543169
538	289444	588	345744	638	407044	688	473344	738	544644
539	290521	589	346921	639	408321	689	474721	739	546121
540	291600	590	348100	640	409600	690	476100	740	547600
541	292681	591	349281	641	410881	691	477481	741	549801
542	293764	592	350464	642	412164	692	478864	742	550564
543	294849	593	351649	643	413449	693	480249	743	552049
544	295936	594	352836	644	414736	694	481636	744	553536
545	297025	595	354025	645	416125	695	483025	745	555025
546	298116	596	355216	646	417316	696	484416	746	556516
547	299209	597	356409	647	418609	697	485809	747	558009
548	300304	598	357604	648	419904	698	487204	748	559504
549	301401	599	358801	649	421201	699	488601	749	561001
550	302500	600	360000	650	422500	700	490000	750	562500

TABLE of Squares of Diameters—*continued.*

No.	Square.	No.	Square.	No.	Square.	No.	Square.	No.	Square.
751	564001	801	641601	851	724201	901	811801	951	904401
752	565504	802	643204	852	725904	902	813604	952	906304
753	567009	803	644809	853	727609	903	815409	953	908209
754	568516	804	646416	854	729316	904	817216	954	910116
755	570025	805	648025	855	731025	905	819025	955	912025
756	571536	806	649636	856	732736	906	820836	956	913936
757	573049	807	651249	857	734449	907	822649	957	915849
758	574564	808	652864	858	736164	908	824464	958	917764
759	576081	809	654481	859	737881	909	826281	959	919681
760	577600	810	656100	860	739600	910	828100	960	921600
761	579121	811	657721	861	741321	911	829921	961	923521
762	580644	812	659344	862	743044	912	831744	962	925444
763	582169	813	660969	863	744769	913	833569	963	927369
764	583696	814	662596	864	746496	914	835396	964	929296
765	585225	815	664225	865	748225	915	837225	965	931225
766	586756	816	665856	866	749956	916	839056	966	933156
767	588289	817	667489	867	751689	917	840889	967	935089
768	589824	818	669124	868	753424	918	842724	968	937024
769	591361	819	670761	869	755161	919	844561	969	938961
770	592900	820	672400	870	756900	920	846400	970	940900
771	594441	821	674041	871	758641	921	848241	971	942841
772	595984	822	675684	872	760384	922	850084	972	944784
773	597529	823	677329	873	762129	923	851929	973	946729
774	599076	824	678976	874	763876	924	853776	974	948676
775	600625	825	680625	875	765625	925	855625	975	950625
776	602176	826	682276	876	767376	926	857476	976	952576
777	603729	827	683929	877	769129	927	859329	977	954529
778	605284	828	685584	878	770884	928	861184	978	956484
779	606841	829	687241	879	772641	929	863041	979	958441
780	608400	830	688900	880	774400	930	864900	980	960400
781	609961	831	690561	881	776161	931	866761	981	962361
782	611524	832	692224	882	777924	932	868624	982	964324
783	613089	833	693889	883	779689	933	870489	983	966289
784	614656	834	695556	884	781456	934	872356	984	968256
785	616225	835	697225	885	783225	935	874225	985	970225
786	617796	836	698896	886	784996	936	876096	986	972196
787	619369	837	700569	887	786769	937	877969	987	974169
788	620944	838	702244	888	788544	938	879844	988	976144
789	622521	839	703921	889	790321	939	881721	989	978121
790	624100	840	705600	890	792100	940	883600	990	980100
791	625681	841	707281	891	793881	941	885481	991	982081
792	627624	842	708964	892	795664	942	887364	992	984064
793	628849	843	710649	893	797449	943	889249	993	986049
794	630436	844	712336	894	799236	944	891136	994	988036
795	632025	845	714025	895	801025	945	893025	995	990025
796	633616	846	715716	896	802816	946	894916	996	992016
797	635209	847	717409	897	804609	947	896808	997	994009
798	636804	848	719104	898	806404	948	898704	998	996004
799	638401	849	720801	899	808201	949	900601	999	998001
800	640000	850	722500	900	810000	950	902500	1000	1000000

SUNDRY RECIPES.

1. *Shell-lac varnish for glass* (Harris).

Put 1 oz. of the shell-lac of commerce into a wide-mouthed 8-ounce phial, containing 5 oz. of well-rectified naphtha, wood or spirit. Close the bottle with a cork, and let it stand in a warm place until perfectly dissolved. Shake the mixture frequently, and pass the fluid through a paper filter; add rectified naphtha to the solution from time to time in such quantities as will enable it to percolate freely through the filter. Change the filter when necessary.

2. *Varnish for paper, for insulating.*

Dissolve 1 oz. of Canada balsam in 2 oz. of spirits of turpentine. Put into a bottle and digest at gentle heat, and filter before being cold.

3. *Varnish for silk.*

Boiled oil, 6 oz., and 2 oz. of clear spirits of turpentine.

4. *Electrical cement.*

Harris prefers the best sealing-wax.

5. *Amalgam for electrical machines.*

Tin 1. Zinc 2. Mercury 4.

The best and cheapest plan for amalgam is to buy it ready made at an electrical instrument maker's. For ebonite places the amalgam should be softer than for glass.

6. *Solder.**

For line wires, Tin 1, Lead 1½; or Tin 1, Lead 1.

7. *Marine glue.* Much used in batteries.

In 12 parts of benzole dissolve 1 of india-rubber, and to the solution add 20 parts of powdered shell-lac, heating the mixture cautiously over a fire. Apply with a brush.

8. *Printing solutions for Bains.*

1 part ferro-cyanide of potassium saturated solution; 1 part nitrate of ammonia saturated solution. 1 part of each solution to 2 parts of water.

9. *Cement for insulators.*

Sulphur, lead, plaster of Paris, with a little glue to prevent it setting quickly.

10. *Muirhead's cement.*

3 lb. Portland cement, 3 lb. rough sand, 4 lb. smith's ashes, 4 lb. resin.

11. *Black cement.*

1 lb. rough sand, 1 lb. smith's ashes, 2 lb. resin.

12. *Siemens' cement.*

12 lb. black iron rust or iron filings, 100 lb. sulphur.

* Soldering (Culley). Connections in apparatus and test-boxes must never be soldered with acids or chloride of zinc. These liquids cannot be entirely removed, and will corrode the metal. If spilled on wood, or even on ebonite, chloride of zinc never dries, and injures the insulation. Resin must always be used.

LOGARITHMS.

To convert Common into Hyperbolic Logarithms.

TABLE.

Common Logarithms.	Hyperbolic Logarithms.
1·	2·3025851
2·	4·6051702
3·	6·9077553
4·	9·2103404
5·	11·5129255
6·	13·8155106
7·	16·1180957
8·	18·4206807
9·	20·7232658

Write the common logarithm (as shown in the following example), and then take from the table the equivalent value of each figure in the hyperbolic logarithms, taking care that the latter are each moved as many places to the right as the corresponding numbers in the common logarithms are. The sum of the whole will be the hyperbolic logarithm required.

Example.—Required the hyp. log. of 3156. The common log. of 3156 is 3·499137; therefore

Common Log.	Hyp. Log.
3·	6·907755
·4	·921034
·09	·207232
·009	·020723
·0001	·000230
·00003	·000069
·000007	·000016
3·499137	8·057061

To convert common into Napierean logarithms, multiply the common logarithms by 2·3025851.

On the following pages will be found a table of Napierean logarithms from 1 to 6, calculated to the second decimal place for finding the exact value of $\log \frac{D}{d}$ for various sizes of telegraph conductor.

In the table of common logarithms will be found a column giving the arithmetical complement of each logarithm; this gives great facility for working sums in proportion, and other calculations in which division becomes necessary; the addition of the arithmetical complement giving the same figures as the subtraction of the original logarithm would have done.

Thus $\frac{140 \times 386}{924}$ becomes

log 140 =	·14613
log 386	·58659
A. Comp. 924	·03432
	·76704 = 585.

Table of natural or Napierean logarithms from 1 to 6, for finding the values of log. $\frac{D}{d}$.

	+ ·00	+ ·01	+ ·02	+ ·03	+ ·04	+ ·05	+ ·06	+ ·07	+ ·08	+ ·09
1·0	0·000	0·010	0·020	0·030	0·039	0·049	0·058	0·068	0·077	0·086
1·1	0·095	0·104	0·113	0·122	0·131	0·140	0·148	0·157	0·166	0·174
1·2	0·182	0·191	0·199	0·207	0·215	0·223	0·231	0·239	0·247	0·255
1·3	0·262	0·270	0·278	0·285	0·293	0·300	0·307	0·315	0·322	0·329
1·4	0·336	0·344	0·351	0·358	0·365	0·372	0·378	0·385	0·392	0·399
1·5	0·405	0.412	0·419	0·425	0·432	0·438	0·445	0·451	0·457	0·464
1·6	0·470	0·476	0·482	0·489	0·495	0·501	0·507	0·513	0·519	0·525
1·7	0·531	0·536	0·542	0·548	0·554	0·560	0·565	0·571	0·577	0·582
1·8	0·588	0·593	0·599	0·604	0·610	0·615	0·621	0·626	0·631	0·637
1·9	0·642	0·647	0·652	0·658	0·663	0·668	0·673	0·678	0·683	0·688
2·0	0·693	0·698	0·703	0·708	0·713	0·718	0·723	0·728	0·732	0·737
2·1	0·742	0·747	0·751	0·756	0·761	0·765	0·770	0·775	0·779	0·784
2·2	0·788	0·793	0·798	0·802	0·806	0·811	0·815	0·820	0·824	0·829
2·3	0·833	0·837	0·842	0·846	0·850	0·854	0·859	0·863	0·867	0·871
2·4	0·875	0·880	0·884	0·888	0·892	0·896	0·900	0·904	0·908	0·912
2·5	0·916	0·920	0·924	0·928	0·932	0·936	0·940	0·944	0·948	0·952
2·6	0·956	0·959	0·963	0·967	0·971	0·975	0·978	0·982	0·986	0·990
2·7	0·993	0·997	1·001	1·004	1·008	1·012	1·015	1·019	1·022	1·026
2·8	1·030	1·033	1·037	1·040	1·044	1·047	1·051	1·054	1·058	1·061
2·9	1·065	1·068	1·072	1·075	1·078	1·082	1·085	1·089	1·092	1·095
3·0	1·099	1·102	1·105	1·109	1·112	1·115	1·118	1·122	1·125	1·128
3·1	1·131	1·135	1·138	1·141	1·144	1·147	1·151	1·154	1·157	1·160
3·2	1·163	1·166	1·169	1·172	1·176	1·179	1·182	1·185	1·188	1·191
3·3	1·194	1·197	1·200	1·203	1·206	1·209	1·212	1·215	1·218	1·221
3·4	1·224	1·227	1·230	1·233	1·235	1·238	1·241	1·244	1·247	1·250
3·5	1·253	1·256	1·258	1·261	1·264	1·267	1·270	1·273	1·275	1·278
3·6	1·281	1·284	1·286	1·289	1·292	1·295	1·297	1·300	1·303	1·306
3·7	1·308	1·311	1·314	1·316	1·319	1·322	1·324	1·327	1·330	1·332
3·8	1·335	1·338	1·340	1·343	1·345	1·348	1·351	1·353	1·356	1·358
3·9	1·361	1·364	1·366	1·369	1·371	1·374	1·376	1·379	1·381	1·384
4·0	1·386	1·389	1·391	1·394	1·396	1·399	1·401	1·404	1·406	1·409
4·1	1·411	1·413	1·416	1·418	1·421	1·423	1·426	1·428	1·430	1·433
4·2	1·435	1·437	1·440	1·442	1·445	1·447	1·449	1·452	1·454	1·456
4·3	1·459	1·461	1·463	1·466	1·468	1·470	1·472	1·475	1·477	1·479
4·4	1·482	1·484	1·486	1·488	1·491	1·493	1·495	1·497	1·500	1·502
4·5	1·504	1·506	1·509	1·511	1·513	1·515	1·517	1·520	1·522	1·524
4·6	1·526	1·528	1·530	1·533	1·535	1·537	1·539	1·541	1·543	1·545
4·7	1·548	1·550	1·552	1·554	1·556	1·558	1·560	1·562	1·564	1·567
4·8	1·569	1·571	1·573	1·575	1·577	1·579	1·581	1·583	1·585	1·587
4·9	1·589	1·591	1·593	1·595	1·597	1·599	1·601	1·603	1·605	1 607
5·0	1·609	1·611	1·613	1·615	1·617	1·619	1·621	1·623	1·625	1·627
5·1	1·629	1·631	1·633	1·635	1·637	1·639	1·641	1·643	1·645	1·647
5·2	1·649	1·651	1·652	1·654	1·656	1·658	1·660	1·662	1·664	1·666
5·3	1·668	1·670	1·671	1·673	1·675	1·677	1·679	1·681	1·683	1·685
5·4	1·686	1·688	1·690	1·692	1·694	1·696	1·697	1·699	1·701	1·703
5·5	1·705	1·707	1·708	1·710	1·712	1·714	1·716	1·717	1·719	1·721
5·6	1·723	1·725	1·726	1·728	1·730	1·732	1·733	1·735	1·737	1·739
5·7	1·740	1·742	1·744	1·746	1·747	1·749	1·751	1·753	1·754	1·756
5·8	1·758	1·760	1·761	1·763	1·765	1·766	1·768	1·770	1·772	1·773
5·9	1·775	1·777	1·778	1·780	1·782	1·783	1·785	1·787	1·788	1·790

Num.	Log.	A. Comp.	Num.	Log.	A. Comp.	Num.	Log.	A. Comp.
0	—∞	∞						
1	·00000	·0000	51	·70757	·29243	101	·00432	·99568
2	·30103	·69897	52	·71600	·28400	102	·00860	·99140
3	·47712	·52288	53	·72428	·27572	103	·01284	·98716
4	·60206	·39794	54	·73239	·26761	104	·01703	·98297
5	69897	·30103	55	·74036	·25964	105	·02119	·97881
6	·77815	·22185	56	·74819	·25181	106	·02531	·97469
7	·84510	·15490	57	·75587	·24413	107	·02938	·97061
8	·90309	·09691	58	·76343	·23657	108	·03342	·96658
9	·95424	·04576	59	·77085	·22915	109	·03743	·96257
10	·00000	·00000	60	·77815	·22185	110	·04139	·95861
11	·04139	·95861	61	·78533	·21467	111	·04532	·95468
12	·07918	·92082	62	·79239	·20761	112	·04922	·95078
13	·11394	·88606	63	·79934	·20066	113	·05308	·94692
14	·14613	·85387	64	·80618	·19382	114	·05690	·94310
15	·17609	·82391	65	·81291	·18709	115	·06070	·93930
16	·20412	·79588	66	·81954	·18046	116	·06446	·93554
17	·23045	·76955	67	·82607	·17393	117	·06819	·93181
18	·25527	·74473	68	·83251	·16749	118	·07188	·92812
19	·27875	·72125	69	·83885	·16115	119	·07555	·92445
20	·30103	·69897	70	·84510	·15490	120	·07918	·92082
21	·32222	·67778	71	·85126	·14874	121	·08279	·91721
22	·34242	·65758	72	·85733	·14267	122	·08636	·91364
23	·36173	·63827	73	·86332	·13668	123	·08991	·91009
24	·38021	·61979	74	·86923	·13077	124	·09342	·90658
25	·39794	·60206	75	·87506	·12494	125	·09691	·90309
26	·41497	·58503	76	·88081	·11919	126	·10037	·89963
27	·43136	·56864	77	·88649	·11351	127	·10380	·89620
28	·44716	·55284	78	·89209	·10791	128	·10721	·89279
29	·46240	·53760	79	·89763	·10237	129	·11059	·88941
30	·47712	·52288	80	·90309	·09691	130	·11394	·88606
31	·49136	·50864	81	·90849	·09151	131	·11727	·88273
32	·50515	·49485	82	·91381	·08619	132	·12057	·87943
33	·51851	·48149	83	·91908	·08092	133	·12385	·87615
34	·53148	·46852	84	·92428	·07572	134	·12710	·87290
35	·54407	·45593	85	·92942	·07058	135	·13033	·86967
36	·55630	·44370	86	·93450	·06550	136	·13354	·86646
37	·56820	·43180	87	·93952	·06048	137	·13672	·86328
38	·57978	·42022	88	·94448	·05552	138	·13988	·86012
39	·59106	·40894	89	·94939	·05061	139	·14301	·85699
40	·60206	·39794	90	·95424	·04576	140	·14613	·85387
41	·61278	·38722	91	·95904	·04096	141	·14922	·85078
42	·62325	·37675	92	·96379	·03621	142	·15229	·84771
43	·63347	·36653	93	·96848	·03152	143	·15534	·84466
44	·64345	·35655	94	97313	·02687	144	·15836	·84164
45	·65321	·34679	95	·97772	·02228	145	·16137	·83863
46	·66276	·33724	96	·98227	·01773	146	·16435	·83565
47	·67210	·32790	97	·98677	·01323	147	·16732	·83268
48	·68124	·31876	98	·99123	·00877	148	·17026	·82974
49	·69020	·30980	99	·99564	·00436	149	·17319	·82681
50	·69897	·30103	100	·00000	·00000	150	·17609	·82391

Num.	Log.	A. Comp.	Num.	Log.	A. Comp.	Num.	Log.	A. Comp.
151	·17898	·82102	201	·30320	·69680	251	·39967	·60033
152	·18184	·81816	202	·30535	·69465	252	·40140	·59860
153	·18469	·81531	203	·30750	·69250	253	·40312	·59688
154	·18752	·81248	204	·30963	·69037	254	·40483	·59517
155	·19033	·80967	205	·31175	·68825	255	·40654	·59347
156	·19312	·80687	206	·31387	·68613	256	·40824	·59176
157	·19590	·80410	207	·31597	·68403	257	·40993	·59007
158	·19866	·80134	208	·31806	·68194	258	·41162	·58838
159	·20140	·79860	209	·32015	·67985	259	·41330	·58670
160	·20412	·79588	210	·32222	·67778	260	·41497	·58503
161	·20683	·79317	211	·32428	·67572	261	·41664	·58336
162	·20952	·79048	212	·32634	·67366	262	·41830	·58170
163	·21219	·78781	213	·32838	·67162	263	·41996	·58004
164	·21484	·78516	214	·33041	·66959	264	·42160	·57840
165	21748	·78252	215	·33244	·66756	265	·42325	·57675
166	·22011	·77989	216	·33445	·66555	266	·42488	·57512
167	·22272	·77728	217	·33646	·66354	267	·42651	·57349
168	·22531	·77469	218	·33846	·66154	268	·42813	·57186
169	·22789	·77211	219	·34044	·65956	269	·42975	·57025
170	·23045	·76955	220	·34242	·65758	270	·43136	·56864
171	·23300	·76700	221	·34439	·65561	271	·43297	·56703
172	·23553	·76447	222	·34635	·65365	272	·43457	·56543
173	·23805	·76195	223	·34830	·65170	273	·43616	·56384
174	·24055	·75945	224	·35025	·64975	274	·43775	·56225
175	·24304	·75696	225	·35218	·64782	275	·43933	·56067
176	·24551	·75449	226	·35411	·64589	276	·44091	·55909
177	·24797	·75203	227	·35603	·64397	277	·44248	·55752
178	·25042	·74958	228	·35793	·64207	278	·44404	·55596
179	·25285	·74715	229	·35984	·64016	279	·44560	·55440
180	·25527	·74473	230	·36173	·63827	280	·44716	·55284
181	·25768	·74232	231	·36361	·63639	281	·44871	·55129
182	·26007	·73993	232	·36549	·63451	282	·45025	·54975
183	·26245	·73755	233	·36736	·63264	283	·45179	·54821
184	·26482	·73518	234	·36922	·63078	284	·45332	·54668
185	·26717	·73283	235	·37107	·62893	285	·45484	·54515
186	·26951	·73049	236	·37291	·62709	286	·45637	·54363
187	·27184	·72816	237	·37475	·62525	287	·45788	·54212
188	·27416	·72584	238	·37658	·62342	288	·45939	·54061
189	·27646	·72354	239	·37840	·62160	289	·46090	·53910
190	·27875	·72125	240	·38021	·61979	290	·46240	·53760
191	·28103	·71897	241	·38202	·61798	291	·46389	·53611
192	·28330	·71670	242	·38382	·61618	292	·46538	·53462
193	·28556	·71444	243	·38561	·61439	293	·46687	·53313
194	·28780	·71220	244	·38739	·61261	294	·46835	·53165
195	·29003	·70996	245	38917	·61083	295	·46982	·53018
196	·29226	·70774	246	·39094	·60906	296	·47129	·52871
197	·29447	·70553	247	·39270	·60730	297	·47276	·52724
198	·29667	·70333	248	·39445	·60555	298	·47422	·52578
199	·29885	70115	249	·39620	·60380	299	·47567	·52433
200	·30103	·69897	250	·39794	·60206	300	·47712	·52288

Num.	Log.	A. Comp.	Num.	Log.	A. Comp.	Num.	Log.	A. Comp.
301	·47857	·52143	351	·54531	·45469	401	·60314	·39686
302	·48001	·51999	352	·54654	·45346	402	·60423	·39577
303	·48144	·51856	353	·54777	·45223	403	·60531	·39469
304	·48288	·51712	354	·54900	·45100	404	·60638	·39362
305	·48430	·51570	355	·55023	·44977	405	·60746	·39254
306	·48572	·51428	356	·55145	·44855	406	·60853	·39147
307	·48713	·51287	357	·55267	·44733	407	·60959	·39041
308	·48855	·51145	358	·55388	·44612	408	·61066	·38934
309	·48996	·51004	359	·55590	·44491	409	·61172	·38828
310	·49136	·50864	360	·55630	·44370	410	·61278	·38722
311	·49276	·50724	361	·55751	·44249	411	·61384	·38616
312	·49415	·50585	362	·55871	·44129	412	·61490	·38510
313	·49554	·50446	363	·55991	·44009	413	·61595	·38405
314	·49693	·50307	364	·56110	·43890	414	·61700	·38300
315	·49831	·50169	365	·56229	·43771	415	·61805	·38195
316	·49969	·50031	366	·56348	·43652	416	·61990	·38091
317	·50106	·49894	367	·56467	·43633	417	·62014	·37986
318	·50243	·49757	368	·56585	·43415	418	·62118	·37882
319	·50379	·49621	369	·56703	·43297	419	·62221	·37779
320	·50515	·49485	370	·56820	·43180	420	·62325	·37675
321	·50651	·49349	371	·56937	·43063	421	·62428	·37572
322	·50786	·49214	372	·57054	·42946	422	·62531	·37469
323	·50920	·49080	373	·57171	·42829	423	·62634	·37366
324	·51055	·48945	374	·57287	·42713	424	·62737	·37263
325	·51188	·48812	375	·57403	·42597	425	·62839	·37161
326	·51322	·48678	376	·57519	·42481	426	·62941	·37059
327	·51455	·48545	377	·57634	·42366	427	·63043	·36957
328	·51587	·48413	378	·57749	·42251	428	·63144	·36856
329	·51720	·48280	379	·57864	·43136	429	·63246	·36755
330	·51851	·48149	380	·57978	·42022	430	·63347	·36653
331	·51983	·48017	381	·58093	·41907	431	·63448	·36552
332	·52114	·47886	382	·58206	·41794	432	·63548	·36452
333	·52244	·47756	383	·58320	·41680	433	·63649	·36351
334	·52375	·47625	384	·58433	·41567	434	·63749	·36251
335	·52504	·47496	385	·58546	·41454	435	·63849	·36151
336	·52634	·47366	386	·58659	·41341	436	·63949	·36051
337	·52763	·47237	387	·58771	·41229	437	·64048	·35952
338	·52892	·47108	388	·58883	·41117	438	·64147	·35853
339	·53020	·46980	389	·58995	·41005	439	·64246	·35754
340	·53148	·46852	390	·59106	·40894	440	·64345	·35755
341	·53275	·46725	391	·59218	·40782	441	·64444	·35556
342	·53403	·46597	392	·59329	·40671	442	·64542	·35458
343	·53529	·46471	393	·59439	·40561	443	·64640	·35360
344	·53656	·46344	394	·59550	·40450	444	·64738	·35262
345	·53782	·46218	395	·59660	·40340	445	·64836	·35164
346	·53908	·46092	396	·59770	·40230	446	·64933	·35066
347	·54033	·45967	397	·59879	·40111	447	·65031	·34969
348	·54158	·45842	398	·59988	·40012	448	·65128	·34872
349	·54283	·45717	399	·60097	·39903	449	·65225	·34775
350	·54407	·45593	400	·60206	·39794	450	·65321	·34678

Num.	Log.	A. Comp.	Num.	Log.	A. Comp.	Num.	Log.	A. Comp.
451	·65418	·34582	501	·69984	·30016	551	·74115	·25885
452	·65514	·34486	502	·70070	·29930	552	·74194	·25806
453	·65610	·34390	503	·70157	·29843	553	·74273	·25727
454	·65706	·34294	504	·70243	·29757	554	·74351	·25649
455	·65801	·34199	505	·70329	·29671	555	·74429	·25571
456	·65896	·34104	506	·70415	·29585	556	·74507	·25493
457	·65992	·34008	507	·70501	·29499	557	·74586	·25414
458	·66087	·33913	508	·70586	·29414	558	·74663	·25337
459	·66181	·33819	509	·70672	·29328	559	·74741	·25259
460	·66276	·33724	510	·70757	·29243	560	·74819	·25181
461	·66370	·33630	511	·70842	·29158	561	·74896	·25104
462	·66464	·33536	512	·70927	·29073	562	·74974	·25026
463	·66558	·33442	513	·71012	·28988	563	·75051	·24949
464	·66652	·33348	514	·71096	·28904	564	·75128	·24872
465	·66745	·33255	515	·71181	·28819	565	·75205	·24795
466	·66839	·33161	516	·71265	·28735	566	·75282	·24718
467	·66932	·33068	517	·71349	·28651	567	·75358	·24642
468	·67025	·32975	518	·71433	·28567	568	·75435	·24565
469	·67117	·32883	519	·71517	·28483	569	·75511	·24489
470	·67210	·32790	520	·71600	·28400	570	·75587	·24413
471	·67302	·32698	521	·71684	·28316	571	·75664	·24336
472	·67394	·32606	522	·71767	·28233	572	·75740	·24260
473	·67486	·32514	523	·71850	·28150	573	·75815	·24185
474	·67578	·32422	524	·71933	·28067	574	·75891	·24109
475	·67669	·32331	525	·72016	·27984	575	·75967	·24033
476	·67761	·32239	526	·72099	·27901	576	·76042	·23958
477	·67852	·32148	527	·72181	·27819	577	·76118	·23882
478	·67943	·32057	528	·72263	·27737	578	·76193	·23807
479	·68034	·31966	529	·72346	·27655	579	·76268	·23732
480	·68124	·31876	530	·72428	·27572	580	·76343	·23657
481	·68215	·31785	531	·72590	·27491	581	·76418	·23582
482	·68305	·31695	532	·72591	·27409	582	·76492	·23508
483	·68395	·31605	533	·72673	·27327	583	·76567	·23433
484	·68485	·31515	534	·72754	·27246	584	·76641	·23359
485	·68574	·31426	535	·72835	·27165	585	·76716	·23284
486	·68664	·31336	536	·72916	·27084	586	·76790	·23210
487	·68753	·31247	537	·72997	·27003	587	·76864	·23136
488	·68842	·31158	538	·73078	·26922	588	·76938	·23062
489	·68931	·31069	539	·73159	·26841	589	·77012	·22988
490	·69020	·30980	540	·73239	·26761	590	·77085	·22915
491	·69108	·30892	541	·73320	·26680	591	·77159	·22841
492	·69197	·30803	542	·73400	·26600	592	·77232	·22768
493	·69285	·30715	543	·73480	·26520	593	·77305	·22694
494	·69373	·30627	544	·73560	·26440	594	·77379	·22621
495	·69461	·30539	545	·73640	·26360	595	·77452	·22548
496	·69548	·30452	546	·73719	·26281	596	·77525	·22475
497	·69636	·30364	547	·73799	·26201	597	·77597	·22403
498	·69723	·30277	548	·73878	·26122	598	·77670	·22330
499	·69810	·30190	549	·73957	·26043	599	·77743	·22257
500	·69897	·30103	550	·74036	·25964	600	·77815	·22185

Num.	Log.	A. Comp.	Num.	Log.	A. Comp.	Num.	Log.	A. Comp.
601	·77887	·22113	651	·81358	·18642	701	·84572	·15428
602	·77960	·22040	652	·81425	·18575	702	·84634	·15366
603	·78032	·21968	653	·81491	·18509	703	·84696	·15304
604	·78104	·21896	654	·81558	·18442	704	·84757	·15243
605	·78176	·21824	655	·81624	·18376	705	·84819	·15181
606	·78248	·21752	656	·81690	·18310	706	·84880	·15120
607	·78319	·21681	657	·81757	·18243	707	·84942	·15058
608	·78390	·21610	658	·81823	·18177	708	·85003	·14997
609	·-8462	·21538	659	·81889	·18111	709	·85065	·14935
610	·78533	·21467	660	·81954	·18046	710	·85126	·14874
611	·78604	·21396	661	·82020	·17980	711	·85187	·14813
612	·78675	·21325	662	·82086	·17914	712	·85248	·14752
613	·78746	·21254	663	·82151	·17849	713	·85309	·14691
614	·78817	·21183	664	·82217	·17783	714	·85370	·14630
615	·78888	·21112	665	·82282	·17718	715	·85431	·14569
616	·78958	·21042	666	·82347	·17653	716	·85491	·14509
617	·79029	·20971	667	·82413	·17587	717	·85552	·14448
618	·79099	·20901	668	·82478	·17522	718	·85612	·14388
619	·79169	·20831	669	·82543	·17457	719	·85673	·14327
620	·79239	·20761	670	·82607	·17393	720	·85733	·14267
621	·79390	·20691	671	·82672	·17328	721	·85794	·14206
622	·79379	·20621	672	·82737	·17263	722	·85854	·14146
623	·79449	·20551	673	·82802	·17198	723	·85914	·14086
624	·79518	·20482	674	·82866	·17134	724	·85974	·14026
625	·79588	·20412	675	·82930	·17070	725	·86034	·13966
626	·79657	·20343	676	·82995	·17005	726	·86094	·13906
627	·79727	·20273	677	·83059	·16941	727	·86153	·13847
628	·79796	·20204	678	·83123	·16877	728	·86213	·13787
629	·79865	·20135	679	·83187	·16813	729	·86273	·13727
630	·79934	·20066	680	·83251	·16749	730	·86332	·13668
631	·80003	·19997	681	·83315	·16685	731	·86392	·13608
632	·80072	·19928	682	·83378	·16622	732	·86451	·13549
633	·80140	·19860	683	·83442	·16558	733	·86510	·13490
634	·80209	·19791	684	·83506	·16494	734	·86570	·13430
635	·80277	·19723	685	·83569	·16431	735	·86629	·13371
636	·80346	·19654	686	·83632	·16368	736	·86688	·13312
637	·80414	·19586	687	·83696	·16304	737	·86747	·13253
638	·80482	·19518	68	83759	·16241	738	·86806	·13194
639	·80550	·19450	689	83822	·16178	739	·86864	·13136
640	·80618	·19382	690	83885	·16115	740	·86923	·13077
641	·80686	·19314	691	·83948	·16052	741	·86982	·13018
642	·80754	·19246	692	·84011	·15989	742	·87040	·12960
643	·80821	·19179	693	·84073	·15927	743	·87099	·12901
644	·80889	·19111	694	·84136	·15864	744	·87157	·12843
645	·80956	·19044	695	·84198	·15802	745	·87216	·12784
646	·81023	·18977	696	·84261	·15739	746	·87274	·12726
647	·81090	·18910	697	·84323	·15677	747	·87332	·12668
648	·81158	·18842	698	·84386	·15614	748	·87390	·12610
649	·81224	·18776	699	·84448	·15552	749	·87448	·12552
650	·81291	·18709	700	·84510	·15490	750	·87506	·12494

Num.	Log.	A. Comp.	Num.	Log.	A. Comp.	Num.	Log.	A. Comp.
751	·87564	·12436	801	·90363	·09637	851	·92993	·07007
752	·87622	·12378	802	·90417	·09583	852	·93044	·06956
753	·87680	·12320	803	·90472	·09528	853	·93095	·06905
754	·87737	·12263	804	·90526	·09474	854	·93146	·06854
755	·87795	·12205	805	·90580	·09420	855	·93197	·06803
756	·87852	·12148	806	·90634	·09366	856	·93247	·06753
757	·87910	·12090	807	·90687	·09313	857	·93298	·06702
758	·87967	·12033	808	·90741	·09259	858	·93349	·06651
759	·88024	·11976	809	·90795	·09205	859	·93399	·06601
760	·88081	·11919	810	·90849	·09151	860	·93450	·06550
761	·88138	·11862	811	·90902	·09098	861	·93500	·06500
762	·88196	·11804	812	·90956	·09044	862	·93551	·06449
763	·88252	·11748	813	·91009	·08991	863	·93601	·06399
764	·88309	·11691	814	·91062	·08938	864	·93651	·06349
765	·88366	·11634	815	·91116	·08884	865	·93702	·06298
766	·88423	·11577	816	·91169	·08831	866	·93752	·06248
767	·88480	·11520	817	·91222	·08778	867	·93802	·06198
768	·88536	·11464	818	·91275	·08725	868	·93852	·06148
769	·88593	·11407	819	·91328	·08672	869	·93902	·06098
770	·88649	·11351	820	·91381	·08619	870	·93952	·06048
771	·88705	·11295	821	·91434	·08566	871	·94002	·05998
772	·88762	·11238	822	·91487	·08513	872	·94052	·05948
773	·88818	·11182	823	·91540	·08460	873	·94101	·05899
774	·88874	·11126	824	·91593	·08407	874	·94151	·05849
775	·88930	·11070	825	·91645	·08355	875	·94201	·05799
776	·88986	·11014	826	·91698	·08302	876	·94250	·05750
777	·89042	·10958	827	·91751	·08249	877	·94300	·05700
778	·89098	·10902	828	·91803	·08197	878	·94349	·05651
779	·89154	·10846	829	·91855	·08145	879	·94399	·05601
780	·89209	·10791	830	·91908	·08092	880	·94448	·05552
781	·89265	·10735	831	·91960	·08040	881	·94498	·05502
782	·89321	·10679	832	·92012	·07988	882	·94547	·05453
783	·89377	·10623	833	·92065	·07935	883	·94596	·05404
784	·89432	·10568	834	·92117	·07883	884	·94645	·05355
785	·89487	·10513	835	·92169	·07831	885	·94694	·05306
786	·89542	·10458	836	·92221	·07779	886	·94743	·05257
787	·89597	·10403	837	·92273	·07727	887	·94792	·05208
788	·89653	·10347	838	·92324	·07676	888	·94841	·05159
789	·89708	·10292	839	·92376	·07624	889	·94890	·05110
790	·89763	·10237	840	·92428	·07572	890	·94939	·05061
791	·89818	·10182	841	·92480	·07520	891	·94988	·05012
792	·89873	·10127	842	·92531	·07469	892	·95036	·04964
793	·89927	·10073	843	·92583	·07417	893	·95085	·04915
794	·89982	·10018	844	·92634	·07366	894	·95134	·04866
795	·90037	·09963	845	·92686	·07314	895	·95182	·04818
796	·90091	·09909	846	·92737	·07263	896	·95231	·04769
797	·90146	·09854	847	·92788	·07212	897	·95279	·04721
798	·90200	·09800	848	·92840	·07160	898	·95328	·04672
799	·90255	·09745	849	·92891	·07109	899	·95376	·04624
800	·90309	·09691	850	·92942	·07058	900	·95424	·04576

Num.	Log.	A. Comp.	Num.	Log.	A. Comp.	Num.	Log.	A. Comp.
901	·95472	·04528	934	·97035	·02965	967	·98543	·01457
902	·95521	·04479	935	·97081	·02919	968	·98588	·01412
903	·95569	·04431	936	·97128	·02872	969	·98632	·01368
904	·95617	·04383	937	·97174	·02826	970	·98677	·01323
905	·95665	·04333	938	·97220	·02780	971	·98722	·01278
906	·95713	·04287	939	·97267	·02733	972	·98767	·01233
907	·95761	·04239	940	·97313	·02687	973	·98811	·01189
908	·95809	·04191	941	·97359	·02641	974	·98856	·01144
909	·95856	·04144	942	·97405	·02595	975	·98900	·01100
910	·95904	·04096	943	·97451	·02549	976	·98945	·01055
911	·95952	·04048	944	·97497	·02503	977	·98989	·01011
912	·95999	·04001	945	·97543	·02457	978	·99034	·00966
913	·96047	·03953	946	·97589	·02411	979	·99078	·00922
914	·96095	·03905	947	·97635	·02365	980	·99123	·00877
915	·96142	·03858	948	·97681	·02319	981	·99167	·00833
916	·96190	·03810	949	·97727	·02273	982	·99211	·00789
917	·96237	·03763	950	·97772	·02228	983	·99255	·00745
918	·96284	·03716	951	·97818	·02182	984	·99300	·00700
919	·96332	·03668	952	·97864	·02136	985	·99344	·00656
920	·96379	·03621	953	·97990	·02091	986	·99388	·00612
921	·96426	·03574	954	·97955	·02045	987	·99432	·00568
922	·96473	·03527	955	·98000	·02000	988	·99476	·00524
923	·96520	·03480	956	·98046	·01954	989	·99520	·00480
924	·96567	·03433	957	·98091	·01909	990	·99564	·00436
925	·96614	·03386	958	·98137	·01863	991	·99607	·00393
926	·96661	·03339	959	·98182	·01818	992	·99651	·00349
927	·96708	·03292	960	·98227	·01773	993	·49695	·00305
928	·96755	·03245	961	·98272	·01728	994	·99739	·00261
929	·96802	·03198	962	·98318	·01682	995	·99782	·00218
930	·96848	·03152	963	·98363	·01637	996	·99826	·00174
931	·96895	·03105	964	·98408	·01592	997	·99870	·00130
932	·96942	·03058	965	·98453	·01547	998	·99913	·00087
933	·96988	·03012	966	·98498	·01502	999	·99957	·00043

ALPHABETS

FOR PRINTING AND SINGLE NEEDLE INSTRUMENTS—RULES FOR SPACING AND SIGNALLING.

A	- —	√
ä (æ)	- — - —	√√
B	— - - -	/\\\
C	— - — -	/√\
D	— - -	/\\
E	-	\
F	- - — -	\\/\
G	— — -	//\
H	- - - -	\\\\
I	- -	\\
J	- — — —	√//
K	— - —	/√
L	- — - -	√\\
M	— —	//
N	— -	/\
O	— — —	///
ö (œ)	— — — -	///\
P	- — — -	√/\
Q	— — - —	//√
R	- — -	√\
S	- - -	\\\
T	—	/
U	- - —	\\√
ü (ue)	- - — —	\\√/
V	- - - —	\\\√
W	- — —	√/
X	— - - —	/\\√
Y	— - — —	/√/
Z	— — - -	//\\
Ch	— — — —	////

French accented é - - — - - (\\/\\) Italian ñ — — - — —
N.B.—Ch is always sent — — — — and never as separate letters.

1	- — — — —	\////
2	- - — — —	\\///
3	- - - — —	\\\//
4	- - - - —	\\\\/
5	- - - - -	\\\\\
6	— - - - -	/\\\\
7	— — - - -	//\\\
8	— — — - -	///\\
9	— — — — -	////\
0	— — — — —	/////

Full Stop	(.)	- - - - - -	\\ \\ \\
Colon	(:)	— — — - - -	///\\\
Semicolon	(;)	— - — - — -	/\/\/\
Comma	(,)	- — - — - —	\/\/\/
Note of Interrogation	(?)	- - — — - -	\\//\\
Note of Admiration	(!)	— — - - — —	//\\//
Hyphen	(-)	— - - - - —	/\\\\/
Apostrophe	(')	- — — — — -	\////\
Parenthesis	()	— - — — - —	/\//\/
Inverted Comma	(" ")	- — - - — -	\/\\/\
Begin another Line		- — — - — - -	\/\/\\
Bar of division (+)		— — — — — —	// // //

Call Signal	— - — - — - —	/\/\/\/
Understand Message	- - - — -	\\\/\
Correction, or rub out	- - - - - - - - -	\\\\\\\\\
End of Message	- — - — - — -	\/\/\/\
Wait	- — - - -	\/\\\
Cleared out, & all right	- — - - — - - — -	\/\\/\\/\

RULES FOR SPACING.

The length of a dot being taken as unit.

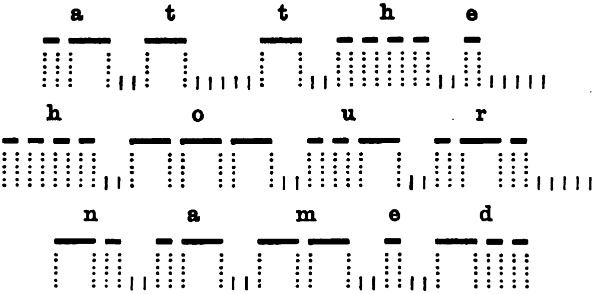
1st. A dash is equal in length to 3 dots.

2nd. The space between the elements of a letter is equal to 1 dot.

3rd. The space between two letters of a word is equal to 3 dots.

4th. The space between two following words is equal to 6 dots.

The above rules are illustrated by the words below, "at the hour named"—



N.B.—For long circuits, especially underground wires, the dots must be made firmly and distinctly, thus, ▬ ▬ ▬ ▬

And not thus . . . .

As dots are shortened by transmission through the Line, Clerks must make them a little longer and closer together than indicated.

RULES FOR SIGNALLING.

1st. Give the Call Signal, and 2nd, the name of "Station to" and "Station from," with the letter **V** between them: thus if LY call MR

	M	**R**	**V**
— - — - — - —	— —	- — -	- - - —

L	**Y**		**M**
- — - -	— - — —	Manchester will reply,	— —

R	**G**
- — -	— — -

To get a word repeated, say - - — — - - - — — - —

To get remainder of Message repeated, say - - — — - -

all after ___________ (word)

If the whole must be repeated, or you cannot read, send

P
- - — — - - all.

To signify all is understood, give - - - — -

To signify wait, give the Signal Wait - — - - - If you require wait for any time, send the number of minutes after Wait, thus:

	5
- — - - -	- - - - - Wait 5 minutes.

To signify that you have made an error, give the correction signal - - - - - - - - - - repeat the last correct word, and continue.

To signify that you have finished a Message, give - — - — - — - (equivalent to PQ of Double Needle Alphabet).

When you have cleared out, and want to signify everything is right, give - — - - — - - — -

Always give the Call Signal before sending anything, to give time to start the Machine; thus, to give Understand—

— - — - — - —   - - - — -

,

Instead of the double-needle colon use - — - — - — ; and

- -   -̇ -   - - instead of DQ.

Initial letters must be separated by the full stop; thus, J. W. Schœne would be sent—

J . W .

- — — —   - -   - -   - -   - — —   - -   - -   - -

S ch œ n e

- - -   — — — —   — — — -   — -   -

Ch must always be sent thus, — — — —, and never as c, h.

Long lines must never be made: if necessary to hold on, give

— - — - — - —   — - — - — - —   — - — -

— - —   — - — - — - — instead of a continuous line.

All figures, doubtful words, and unknown proper names in a message, must be repeated back, followed by the - - — — - - signifying—Is this correct? The Sending Station will reply - - - - — - if correct, and go on with the next message.

Fractions are sent thus, $98^{10}/_{16}$.

9 8 1

— — — — -   — — — - -   - — — — —

0

— — — — —   — —   — —   — —

1 6

- — — — —   — - - - - **leaving a good space between the figures and the fractions**; and in *repeating* them, spell the Enumerator always thus—

9 8 t e n

- — — — —   — — — - -   —   -   — -

R

1 6

(this is to ensure correctness).

o n e 2

$\frac{1}{2}$ would be repeated

&c.

1 0 0

0 0

would be repeated

t e n t h o u s

for brevity and for greater certainty.

A good space must always be left between whole numbers and their fractions; $115\frac{11}{15}$ would be sent thus—

1

1 5 1

1

1 5

to distinguish it from $1{,}151\frac{1}{15}$ The Numerator 11 being spelled in the Collating.

c o

The word "couché" would be sent thus,

u ch é

When a Station does not read you, send the letters to enable him to adjust his Apparatus. In a circuit containing one or more translating Stations, if there be necessity for calling the attention of those Stations to the translators, give the letter h several times, which is to be understood by the Translating Clerk to signify that there is something wrong and requiring his immediate attention.

The call for "all Stations" (C Q) is the letter s - - -   - - -
- - - &c., given during one minute.

When the number of words in a received message is incorrect, the Receiving Station must repeat the actual number to the Sending Station, thus:—

If 28 W. be telegraphed, and only 27 received, say - - — — — (2)
— — - - - (7)   - — — (w)   - - — — - - (p)

Should 27 be right, the Sending Station will reply, - - — — — (2)
— — - - - (7)   - - - - — - but if there still be 28 words, the Sending Station will say 28 W., and repeat the first letters of every word, when the Receiving Station can easily detect the error or omission, and get the word repeated.

N.B.—For the Single Needle Alphabet, the Beat to the right (/) is equivalent to the (—), and the Beat to the left (\) is equivalent to the dot (-). The "understand," and not "understand," are the same as in the Double Needle Alphabet.

The end of a word is expressed by a pause.

In Single Needle, the code signals FI before, and IF after the figures are to be used (but not in printing).

Figures are to be made very distinctly.

N.B.—As all Figures contain 5 signals, and all Stops 6, the receiver can read them off with great accuracy.

The following Signals are much used on the Continent, though not officially recognised:—

- - - — - - - Telegraph.

— — — - — — — Drahtantwort.

- - - — ia for ja or yes, and is used in place of - — - — - — - and - - - - — -

Tables to assist the reading of Telegraphic Despatches.

(*Sir Charles Wheatstone, F.R.S.*)

The same telegraphic alphabet has, by universal agreement, been adopted by all the countries of the world in which telegraphic communication exists. At present, its use is however almost exclusively limited to the clerks whose business it is to send and receive the messages. If it were deemed important or desirable that the message should be transmitted to the person to whom it was addressed in the exact manner in which it was received, so as not to incur the intermediate errors of translation, it would become necessary that the receiver should be acquainted with the language in which it was written. Now this is by no means a difficult thing to attain, and it would require but little time if resolutely set about. But the preliminary task of committing the meaning of the signs to memory, comparatively easy as it is, may be considerably lightened by a very simple expedient. To refer to a table of 26 characters in order to translate a despatch, letter by letter, is a very tedious matter, and the process may be much abridged by forming a table showing the formation of the more compound characters from the more elementary ones. Such a table can be much more rapidly referred to; and it will be found that, by its aid, a telegraphic despatch can be read accurately without any previous knowledge, and without much loss of time. After a little practice in thus deciphering, the

meanings of the signs will, without any great effort, become fixed in the mind, and the messages be read in future fluently and without aid.

1 Element

•	e
—	t

2 Elements

		—
•	i	a
—	n	m

3 Elements

	•	—
• •	s	u
• —	r	w
— •	d	k
— —	g	o

4 Elements

	• •	• —	— •	— —
• •	h	v	f	ü
• —	l	ä	p	j
— •	b	x	c	y
— —	z	q	ö	ch

The manner of using the above tables is as follows:— The person wishing to translate the despatch commences at the first letter, noticing of how many elementary signs (dots or dashes), it is composed. When it consists of one element only, its meaning is given directly by reference to the first table; when of two elements, by the second table, the first element on the left being found in the front vertical column, and the second at the heading of the columns containing the letters; when the letter consists of three elements, it is found by reference to the third table, the first two elements being in the front, and the last one at the head, of the columns; when of four elements, the first two are found in the front of the fourth table, and the last two at the head of the columns.

As an example, suppose we wish to translate the word · — — ·   · —   · · ·   —   ·

Here the first letter consists of four elements; we look, therefore, in the corresponding table for the two first elements as they stand in order in the front, and find them opposite the second horizontal line of letters, which we follow across until at the head of the third vertical column we see the remaining two elements of the letter "*p*," which is written at the point of intersection. The next letter consists of two elements, the first being a dot; we refer to the table of two elements, and find the letter corresponding to be "*a*." The third letter has three elements, all dots; we refer to the table of three elements, and find this to be "*s*." The fourth letter is a single dash, which the table of *one element*

informs us is "*t.*" The last letter is also a single element, "*e.*"

Sir Charles Wheatstone has constructed a machine for the purpose of printing in Roman characters any despatch which may be received in the Morse character. The apparatus is constructed with a suitable type-printing arrangement, which is actuated by the depression of eight finger keys placed in front of it, in two rows of four in each. The upper row represents dots, the lower dashes. In order to print any letter in Roman type which is received in Morse characters, the operator has only to depress in succession the finger keys of the two rows, commencing always with the first one of one of the rows, then the second of one of them, then the third, and so on, according as the letter is made up of dots or dashes. By a very ingenious application of the theory of numbers, these depressions release the requisite types, allowing 32 letters and figures to be printed.

Table showing the relation between the strain on the Grapnel Rope and the

Strain on Cable.	Number of fathoms the bight has													
	15	**20**	**30**	**40**	**50**	**75**	**100**	**200**	**300**	**400**	**500**	**600**	**700**	**800**
	Corresponding strain on Grapnel Rope. The unit of strain is the													
·5	·24	·27	·34	·39	·43	·52								
1·0	·34	·39	·48	·56	·62	·76	·87	1·20	1·40	1·60	1·32	1·83	1·90	1·95
1·5	·42	·48	·61	·68	·76	·94	1·08	1·45	1·75	2·02	2·25	2·40	2·53	2·60
2·0	·48	·56	·69	·79	·88	1·0	1·25	1·70	2·1	2·38	2·53	2·85	3·00	3·18
2·2	·51	·59	·72	·83	·93	1·14	1·36	1·80	2·20	2·50	2·75	3·00	3·20	3·37
2·4	·53	·61	·75	·87	·97	1·19	1·38	1·85	2·25	2·54	2·84	3·10	3·30	3·50
2·6	·55	·64	·78	·90	1·01	1·24	1·43	1·90	2·30	2·70	3·02	3·30	3·55	3·75
2·8	·58	·68	·81	·94	1·05	1·29	1·48	2·00	2·40	2·80	3·20	3·45	3·70	3·90
3·0	·59	·68	·84	·97	1·09	1·33	1·52	2·05	2·50	2·95	3·30	3·60	3·90	4·10
3·2	·61	·71	·87	1·00	1·12	1·37	1·58	2·10	2·60	3·10	3·42	3·75	4·00	4·20
3·4	·63	·73	·90	1·04	1·16	1·42	1·62	2·22	2·70	3·2	3·55	3·90	4·15	4·40
3·6	·65	·75	·92	1·07	1·19	1·46	1·68	2·30	2·80	3·3	3·65	4·00	4·25	4·55
3·8	·67	·77	·95	1·10	1·24	1·50	1·72	2·35	2·90	3·40	3·78	4·8	4·38	4·63
4·0	·69	·80	·97	1·13	1·26	1·54	1·78	2·45	3·00	3·50	3·87	4·20	4·50	4·80
4·2	·71	·82	1·00	1·15	1·29	1·58	1·82	2·50	3·05	3·50	4·00	4·30	4·60	4·90
4·4	·72	·83	1·02	1·18	1·32	1·62	1·88	2·55	3·20	3·70	4·10	4·45	4·80	5·10
4·6	·74	·85	1·04	1·21	1·35	1·65	1·92	2·60	3·20	3·70	4·15	4·50	4·85	5·15
4·8	·75	·87	1·07	1·23	1·39	1·69	1·95	2·70	3·20	3·75	4·20	4·60	4·90	5·25
5·0	·77	·89	1·09	1·26	1·41	1·72	1·98	2·80	3·35	3·90	4·35	4·70	5·05	5·38
5·5	·81	·93	1·14	1·32	1·48	1·81	2·08	2·90	3·60	4·10	4·60	4·95	5·30	5·65
6·0	·85	·97	1·20	1·38	1·55	1·89	2·18	3·00	3·70	4·30	4·80	5·20	5·60	6·00
6·5	·88	1·00	1·24	1·44	1·61	1·97	2·28	3·20	3·90	4·50	5·00	5·50	5·90	6·30
7·0	·91	1·06	1·29	1·49	1·67	2·04	2·36	3·20	4·00	4·65	5·20	5·70	6·15	6·50
7·5	·94	1·09	1·34	1·55	1·73	2·11	2·43	3·30	4·10	4·80	5·37	5·90	6·35	6·78
8·0	·98	1·13	1·38	1·60	1·79	2·18	2·52	3·30	4·20	4·90	5·60	6·10	6·60	7·00
9·0	1·04	1·20	1·46	1·69	1·89	2·32	2·68	3·50	4·40	5·20	5·90	6·50	7·00	7·50
10·0	1·09	1·26	1·55	1·70	1·99	2·44	2·82	3·70	4·50	5·40	6·20	6·90	7·40	7·90
11·0	1·14	1·32	1·63	1·87	2·10	2·56	2·93	3·90	4·80	5·70	6·55	7·20	7·80	8·30

strain at the same time on the Cable when it is being raised on the bight.

been raised from the bottom.

900	1,000	1,100	1,200	1,300	1,400	1,500	1,600	1,700	1,800	1,900	2,000
weight of 1000 fathoms of Cable in water, or nearly one knot.											
1·98	2·00										
2·75	2·82	2·88	2·93	2·96	2·98	3·00					
3·22	3·45	3·55	3·65	3·72	3·80	3·86	3·90	3·95	3·97	3·99	4·00
3·43	3·68	3·80	3·92	4·00	4·10	4·17	4·25	4·31	4·34	4·37	4·39
3·70	3·90	4·03	4·15	4·27	4·37	4·45	4·53	4·60	4·65	4·70	4·73
3·99	4·10	4·25	4·40	4·50	4·60	4·70	4·80	4·88	4·95	5·00	5·07
4·10	4·28	4·44	4·60	4·70	4·85	4·95	5·05	5·15	5·25	5·30	5·38
4·30	4·48	4·63	4·80	4·95	5·07	5·18	5·30	5·40	5·50	5·55	5·63
4·45	4·63	4·84	5·00	5·15	5·30	5·40	5·54	5·67	5·77	5·85	5·93
4·60	4·80	5·00	5·20	5·35	5·50	5·65	5·75	5·90	6·00	6·1	6·20
4·80	4·98	5·16	5·35	5·53	5·70	5·85	6·01	6·10	6·33	6·35	6·45
4·90	5·12	5·35	5·55	5·73	5·90	6·06	6·20	6·35	6·47	6·60	6·70
5·05	5·30	5·55	5·75	5·95	6·10	6·25	6·40	6·55	6·70	6·80	6·90
5·15	5·35	5·60	5·85	6·05	6·25	6·42	6·60	6·75	6·90	7·05	7·15
5·35	5·60	5·80	6·05	6·25	6·45	6·62	6·70	6·98	7·13	7·27	7·38
5·45	5·72	5·95	6·20	6·40	6·60	6·80	7·00	7·18	7·32	7·48	7·58
5·50	5·85	6·10	6·30	6·55	6·77	6·98	7·13	7·32	7·50	7·65	7·80
5·70	6·00	6·25	6·50	6·70	6·9	7·12	7·30	7·50	7·70	7·85	7·98
5·95	6·25	6·55	6·80	7·10	7·3	7·55	7·78	8·00	8·17	8·33	8·48
6·35	6·54	6·94	7·20	7·50	7·7	7·92	8·15	8·38	8·57	8·77	8·93
6·60	6·92	7·25	7·54	7·80	8·07	8·38	8·55	8·8	9·0	9·20	9·34
6·90	7·20	7·60	7·90	8·15	8·40	8·65	8·90	9·15	9·37	9·60	9·80
7·17	7·40	8·00	8·10	8·16	8·45	8·75	9·0	9·25	9·50	9·75	10·20
7·40	7·75	8·10	8·40	8·75	9·05	9·32	9·6	9·90	10·15	10·4	10·65
7·90	8·25	8·60	9·00	9·30	9·65	9·93	10·3	10·35	10·8	11·10	11·30
8·40	8·80	9·30	9·70	10·14	10·50	10·80	11·1	11·35	11·6	11·8	12·0
8·80	9·20	9·60	10·0	10·40	10·75	11·1	11·45	11·80	12·1	12·4	12·65

TABLE showing tension on any Submarine Cable when raised on the bight in different depths.

Slack paid out.	Strain on Cable in terms of weight of one knot of Cable in water.														
	Depth of water in fathoms.														
	15	20	30	40	50	60	70	80	90	100	500	1,000	1,500	2,000	2,500	1 knot.
%															
·05	9·5	12·7	19	25·5	..	..	..	..	..	..	..	..	..	..	..	645
·10	5·02	6·7	10	13·4	16·8	20·0	..	..	..	..	..	..	..	..	..	340
·15	5·35	4·5	6·7	8·9	11·2	13·4	15·6	17·8	20·1	22·3	..	..	..	..	..	226
·20	2·34	3·12	4·7	6·22	7·8	9·3	10·9	12·4	14·0	15·6	..	..	..	..	..	158
·30	1·61	2·15	3·2	4·3	5·4	6·4	7·5	8·6	9·7	10·7	..	..	..	..	..	109
·40	1·29	1·72	2·6	3·4	4·3	5·1	6·0	6·9	7·7	8·6	..	..	..	..	..	87
·50	1·03	1·38	2·07	2·75	3·4	4·1	4·8	5·5	6·2	6·9	..	..	..	..	..	70
·75	0·65	0·87	1·30	1·73	2·2	2·60	3·0	3·46	3·9	4·3	21·6	..	..	..	..	44
1·0	0·52	0·69	1·04	1·38	1·72	2·06	2·41	2·75	3·1	3·4	17·2	..	..	..	..	35
¼	·40	·54	0·81	1·08	1·35	1·62	1·89	2·16	2·4	2·7	13·5	..	..	..	..	27
½	·34	·46	·69	·91	1·14	1·37	1·60	1·83	2·06	2·29	11·4	22·8	..	..	..	23
¾	·30	·39	·59	·79	·99	1·18	1·38	1·58	1·78	1·97	9·87	19·7	..	..	..	20
2	·26	·35	·52	·70	·87	1·04	1·22	1·40	1·57	1·74	8·7	17·4	26·1	..	..	18
¼	·23	·31	·47	·62	·78	·93	1·09	1·25	1·40	1·56	7·8	15·6	23·4	..	..	15·8
½	·21	·28	·42	·56	·70	·84	·98	1·14	1·24	1·40	7·0	14·0	21·0	28·0	..	14·2
¾	·19	·26	·39	·51	·64	·77	·90	1·03	1·16	1·29	6·4	13·9	19·3	28·0	..	13·0
3	·18	·24	·36	·48	·60	·72	·84	·96	1·08	1·20	6·0	12·0	18·0	24·0	..	12·0
¼	·16	·22	·33	·44	·55	·66	·77	·88	·99	1·10	5·1	11·0	16·5	22·0	..	11·1

½	·15	·20	·31	·41	·52	·62	·72	·83	·93	1·04	5·2	10·3	15·5	20·6	25·7	10·4
¾	·14	·19	·28	·39	·48	·58	·68	·77	·88	·97	5·9	9·7	14·5	19·4	24·2	9·8
4	·14	·18	·27	·37	·46	·55	·64	·73	·82	·92	4·6	9·2	13·8	18·4	23·0	9·3
¼	·13	·17	·27	·34	·43	·52	·60	·69	·78	·86	4·3	8·6	12·9	17·2	21·5	8·7
½	·12	·16	·25	·33	·41	·49	·57	·66	·74	·82	4·1	8·2	12·3	16·4	20·5	8·3
¾	·12	·16	·23	·31	·39	·47	·55	·63	·70	·78	3·9	7·9	11·8	15·8	19·7	7·9
5	·11	·15	·22	·30	·37	·45	·52	·60	·67	·75	3·7	7·4	11·2	15·0	17·7	7·6
6	·09	·13	·19	·25	·32	·38	·44	·51	·57	·63	3·2	6·3	9·5	12·6	15·8	6·4
7	·08	·11	·17	·22	·28	·33	·39	·45	·50	·56	2·8	5·6	8·4	11·6	14·0	5·7
8	·07	·10	·15	·20	·25	·30	·35	·40	·45	·50	2·5	5·0	7·6	10·0	12·6	5·1
9	·07	·09	·14	·18	·23	·27	·32	·36	·41	·45	2·3	4·5	6·8	9·0	11·3	4·6
10	·06	·08	·13	·17	·21	·25	·29	·34	·38	·42	2·1	4·2	6·3	8·4	10·5	4·3
11	·06	·08	·12	·16	·20	·23	·27	·31	·35	·39	1·96	3·9	5·9	7·8	9·8	4·0
12	·05	·07	·11	·15	·18	·22	·25	·29	·33	·37	1·82	3·6	5·5	7·3	9·1	3·7
13	·05	·07	·10	·14	·17	·21	·24	·28	·31	·34	1·72	3·4	5·2	6·9	8·6	3·5
14	·05	·07	·10	·13	·16	·20	·23	·26	·29	·33	1·64	3·3	4·9	6·6	8·2	3·3
15	·05	·06	·09	·12	·16	·19	·22	·25	·28	·31	1·56	2·1	4·7	6·2	7·8	3·16
16	·05	·06	·09	·12	·15	·18	·21	·24	·27	·30	1·49	3·0	4·5	6·0	7·9	3·03
17	·04	·06	·09	·11	·14	·17	·20	·23	·26	·29	1·43	2·9	4·2	5·7	7·1	2·90
18	·04	·05	·08	·11	·14	·17	·19	·22	·25	·27	1·38	2·8	4·14	5·5	6·9	2·79
19	·04	·05	·08	·11	·13	·16	·19	·21	·24	·27	1·32	2·6	3·9	5·3	6·6	2·69
20	·04	·05	·08	·10	·13	·15	·18	·20	·23	·26	1·28	2·6	3·8	5·1	6·4	2·60
21	·04	·05	·07	·10	·12	·15	·17	·20	·22	·25	1·24	2·5	3·7	5·0	6·2	2·53
22	·04	·05	·07	·10	·12	·14	·17	·19	·22	·24	1·20	2·4	3·6	4·8	6·0	2·45
23	·04	·05	·07	·09	·11	·14	·16	·19	·21	·24	1·18	2·36	3·5	4·7	5·9	2·39
24	·03	·05	·07	·09	·11	·14	·16	·18	·21	·23	1·15	2·30	3·4	4·6	5·8	2·33
25	·03	·04	·07	·09	·11	·13	·16	·18	·20	·22	1·12	2·24	3·3	4·5	5·6	2·27
26	·03	·04	·07	·09	·11	·13	·15	·17	·20	·22	1·09	2·18	3·3	4·4	5·4	2·22
27	·03	·04	·06	·09	·11	·13	·15	·17	·19	·21	1·07	2·15	3·2	4·3	5·4	2·18
28	·03	·04	·06	·08	·10	·13	·15	·17	·19	·21	1·04	2·09	3·1	4·2	5·2	2·13

ELECTRICAL TESTS OF VARIOUS

CABLE. (G.P. Core.)	Date.	Length Laid. Knots.	Diameters. Copper d mils.	Core D mils.	Logarithm of $\frac{D}{d}$ (approx.)*
1. **Persian Gulf**	1864	1148	110	380	·53781
2. **Atlantic**	1865	1896	147	467	·52763
3. **Persian Gulf**	1866	160	110	380	·53781
4. **Atlantic**	1866	1852	147	467	·52763
5. **England and Hanover**	1866	224	87	280	·53655
6. **Placentia Bay and Sydney**	1867	112·1 / 188·7	102	348	·55266
7. **Cuba and Florida:** Havannah to Key West / Key West to Punta Rassa	1867	125·4 / 119·9	87	290	·55750
8. **Anglo-Mediterranean**	1868	927	103	327	·52763
9. **French Atlantic**	1869	2584	168	470	·47129
Do. **St. Pierre**		749	87	282	·53655
10. **British Indian:** Suez-Aden	1870	1461	92	304	·54530
Aden-Bombay		1817	113	358	·52763
11. **Falmouth and Gibraltar**	1870	1431	92	304	·54530
12. **Gibraltar and Malta**	1870	1025	92	304	·54530
13. **Marseilles, Algiers and Malta:** Marseilles to Bona	1870	447·6	87	272	·50242
Bona to Malta		378·4	87	272	·50242
14. **Anglo-Mediterranean Duplicate§**	1870	..	..	..	..
15. **British Indian Extension**	..	1756	92	304	·54530
16. **China Telegraph**	..	2640	92	304	·54530
17. **British Australian**	..	2526	92	304	·54530

* The value of $\frac{D}{d}$ is increased 5% in these instances in which the conductor is a strand.

RECENT TELEGRAPH CABLES.

Resistance of Conductor at 24° Cent.		Resistance of Dielectric at 24° Cent.		Electro-static Capacity.		Approximate Resistance when laid irrespective of temperature and pressure.	
Resistance per knot, Ohms.	Specific Conductivity, Pu. Copper = 100.	Resistance per knot, Megohms.	Specific Resistance, Megohms.†	Electro-static Capacity per knot, Microfarads.	Specific Inductive Capacity, Microfarads.‡	Resistance of Conductor, Ohms, per knot.	Resistance of Dielectric, Megohms, per knot.
6·25	84·79	190	1002	0·3486	·0661	Fao-Bushire 6·46 Bushire, Mussendum 6·21 Mussendum, Gwader 6·40 Gwader, Kurrachee 6·30	495· 326· 342· 239·
4·27	93·09	349	1805	0·3535	·0684	4·01	2945
6·01	88·17	395	2084	0·3312	·0628	. .	. .
4·20	94·63	342	1768	0·3535	·0684	3·89	2437
12·07	92·32	239	1213	0·3447	·0679	11·71	1010
8·96	88·71	455	2237	0·3566	·0725	Placentia & St. Pierre 8·32 St. Pierre & Sydney 8·34	4498 4257
12·38	90·02	464	2270	0·3507	·0717	11·83 12·37	1268 175·0
8·73	91·05	496	2565	0·4500	·0870	8·23	2631
3·16	94·33	235	1361	0·4295	·0742	2·93	5200
12·03	92·63	266	1350	0·3740	·0737	11·12	2910
10·42	95·35	329	1646	0·3580	·0716	10·26	5700
7·02	94·36	278	1441	0·3610	·0696	6·52	1899
10·508	94·55	214	1070	0·3645	·0729	10·13	1419
10·508	94·55	214	1070	0·3480	·0696		
12·03	92·62	273	1482	0·286	·0527	11·65	2329
12·17	91·57	238	1291	0·286	·0527	11·66	734
. .	. .	. .	. .	. .	. .	. .	. .
10·508	94·55	235	1176	0·3400	·0680	. .	. .
. .	. .	. .	. .	. .	. .	. .	. .
10·907	91·20	194	970	0·2920	·0584	. .	. .

† The specific resistance is taken as that of a cube knot.
‡ The specific capacity is taken as the capacity of a cube knot.
§ This cable is made up of lengths of various cables.

ELECTRICAL TESTS OF VARIOUS

CABLE. (Hooper's Core.)	Date.	Length Laid. Knots.	Diameters. Copper d mils.	Core D mils.	Logarithm of $\frac{D}{d}$ (approx.)
18. **Persian Gulf** . . .	1868	525	110	309	·46125
19. **Anglo-Danish** . .	1868	365	110	290	·43410
20. **Anglo-Norwegian** .	1869	240	110	290	·43410
21. **Moen Banholm** . .	1869	82	80	241	·50373
22. **Aland Cable** . . .	1869	87	110	290	·43410
23. **Shetland Cables**. .	1869	69 9	80 110	241 290	·50373 ·43410
24. **North China**:					
Hong-Kong—Shangai Shangai—Posietta. .	1870	1098 1198	147	318	·36169

RECENT TELEGRAPH CABLES—(*continued*).

Resistance of Conductor at 24° Cent.		Resistance of Dielectric at 24° Cent.		Electro-static Capacity.		Approximate Resistance when laid irrespective of temperature and pressure.	
Resistance per knot, Ohms.	Specific Conductivity, Pu. Copper = 100	Resistance per knot, Megohms.	Specific Resistance, Megohms.	Electro-static Capacity per knot, Microfarads.	Specific Inductive Capacity, Microfarads.	Resistance of Conductor, Ohms.	Resistance of Dielectric, Megohms.
5·60	93·64	3900	2580	0·3490	·0528		
7·06	93·82	4430	2780	0·3680	·0585		
7·06	93·82	4500	2780	0·3680	·0585		
14·37	92·19	4000	2170	0·3120	·0576		
7·06	93·82	4500	2780	0·3680	·0585		
14·37	92·19	4000	2170	0·3120	·0576		
7·06	92·82	3890	2440	0·3690	·0587		
4·23	93·96	4000	3020	0·4400	·0583	Not yet laid.	

MECHANICAL DATA OF VARIOUS

CABLE.	Date.	Length laid.	WEIGHT		
			Copper.	Insulator.	Iron.
		Knots.	Lbs.	Lbs.	Tons.
1. Persian Gulf	1864	1148	225	275	3·060
2. Atlantic	1865	1896	300	400	0·632
3. Persian Gulf	1866	160	225	275	3·060
4. Atlantic	1866	1852	300	400	0·632
5. England and Hanover .	1866	224	107	150	17·065 8·100
6. Placentia Bay and Sydney	1867	112·1 188·7	150	230	2·150
7. Cuba and Florida . . .	1867				
Havannah to Key West. Key West to Punta Rassa	..	125·4 119·9	107	166	2·100
8. Anglo-Mediterranean . .	1868	927	150	200	
9. French Atlantic . . .	1869				
Brest—St. Pierre . .	..	2584	400	400	17·795
,, ,, . .	..				4·605
,, ,, . .	..				·709
St. Pierre—Duxbury .	..	749	107	150	14·972
,, ,, .	..				4·753
,, ,, .	..				1·949
10. British Indian	1870				
Suez—Aden	..	1460·66	120	175	9·758
,, ,, ...	..				2·725
,, ,, ...	..				1·193
Aden—Bombay . . .	..	1817·43	180	240	9·759
,, ,, . . .	..				11·705
,, ,, . . .	..				5·429
,, ,, . . .	..				2·851
,, ,, . . .	..				1·186
11. Falmouth and Gibraltar .	1870				
Falmouth—Lisbon . .	..	27·75	120	175	10·604
,, ,, . .	..	144·80	..	..	3·018
,, ,, . .	..	651·06	..	..	·709
Lisbon—Gibraltar . .	..	12·00	120	175	10·604
,, ,, . .	..	15·00	..	..	3·018
,, ,, . .	..	274·00	..	..	·923
,, ,, . .	..	45·00	..	..	5·917
12. Gibraltar and Malta . .	1870	4·00	120	175	10·604
,, ,, . .	..	251·97	..	..	3·018
,, ,, . .	..	846·29	..	..	·923
,, ,, . .	..	2·81	..	..	5·917

RECENT TELEGRAPH CABLES.

PER KNOT.			REMARKS.
Hemp.	Asphalte.	Complete.	
Tons.	Tons.	Tons.	
..	..	3·73	
·8055	None	1·75	
..	..	3·73	
·8055	None	1·75	
·3396	·637	18·49	Shore ends.
·4000	2·080	10·94	Main.
·1804	None	2·50	Placentia and St. Pierre. St. Pierre and Sydney.
·2782	None	2·50	
·217	2·113	20·447	Shore ends.
·368	·921	6·246	Intermediate.
·104	·487	1·652	Main.
·109	1·563	16·760	Shore ends.
·528	·879	6·276	Intermediate.
·1095	·700	2·875	Main.
·540	·927	11·412	Shore ends.
·131	·330	3·286	Intermediate.
·189	·459	2·712	Main.
·725	1·080	11·737	Shore end (Aden).
·146	·698	12·737	,, ,, (Bombay).
·325	·691	6·633	Intermediate (No. 1).
·083	·345	3·414	,, (No. 2).
·146	·352	1·872	Main.
·725	1·080	11·737	Shore ends.
·090	·350	3·420	1st Intermediate.
·104	·487	1·652	1st Main.
·725	1·080	11·737	Shore ends.
·090	·350	3·420	1st Intermediate.
·063	·244	1·535	2nd Main.
·325	·691	6·633	2nd Intermediate.
·725	1·080	11·737	Shore ends.
·090	·350	3·420	1st Intermediate.
·063	·244	1·535	2nd Main.
·325	·691	6·633	2nd Intermediate.

MECHANICAL DATA OF VARIOUS

CABLE.	Date.	Length laid.	WEIGHT Copper.	Insulator.	Iron.
		Knots.	Lbs.	Lbs.	Tons.
13. Marseilles, Algiers and Malta	1870				
Marseilles to Bona . .	..	16	107	166	10·604
" " . .	..	486	..	..	1·054
Bona to Malta . . .	..	24	107	166	10·604
" " . . .	..	336	..	..	1·211
14. Anglo-Mediterranean Duplicate	1870				
15. British Indian Extension .	1870				
Penang—Singapore . .	..	1447·17	120	175	9·518
" " . .	..				2·696
" " . .	..				2·761
Penang—Madras. . .	..	387	120	175	5·113
" " . . .	..				1·099
16. China Telegraph . . .	..	1632	107	140	9·514
" " . . .	..				2·831
" " . . .	..				1·913
17. British Australian . . .	1870				
Batavia and Singapore .	..	579	107	140	9·514
" " .	..				2·831
Batavia and Port Darwin	..	..	107	140	9·514
" "	..	..	..	..	1·193
18. Persian Gulf	1868	525	225	200	3·06
19. Anglo-Danish	1868	365	180	180	2·40
20. Anglo-Norwegian	1869	240	180	180	2·40
21. Moen-Banholm. . . .	1869	82	90	130	..
22. Aland Cable	1869	87	180	180	2·40
23. Shetland Cables . . .	1869	69	90	130	1·04
		9	180	180	6·00
24. North China	1870				
Hong-Kong—Shanghai .	..	685	300	200	1·10
" " .	..	272	..	..	2·10
" " .	..	111	..	..	6·60
" " .	..	30	..	..	1·52
Shanghai—Posietta . .	..	990	300	200	1·10
" " . .	..	92	..	..	2·40
" " . .	..	96	..	..	6·60
" " . .	..	20	..	..	1·52

RECENT TELEGRAPH CABLES—*continued.*

PER KNOT.			REMARKS.
Hemp.	Asphalte.	Complete.	
Tons.	Tons.	Tons.	
·725	1·080	11·737	Shore ends.
·140	·346	1·864	Main.
·725	1·080	11·737	Shore ends.
·150	·360	1·880	Main.
·587	1·304	11·521	Shore ends.
·108	·443	3·375	Intermediate.
·122	·385	3·397	Main.
·273	·810	6·331	Shore ends.
·066	·247	1·541	Main.
·666	1·371	11·412	Shore ends.
·103	·443	3·286	Intermediate.
·259	·459	2·712	Main.
·666	1·371	11·665	Shore ends.
·103	·443	3·490	Main.
·666	1·371	11·665	Shore ends.
·107	·393	1·796	Main.
..	..	3·73	.. Hooper's India-rubber.
..	..	3·00	.. Hooper's India-rubber.
..	..	3·00	.. Hooper's India-rubber.
..	..	..	.. Hooper's India-rubber.
..	..	3·00	.. Hooper's India-rubber.
·145	·260	1·64	.. Hooper's India-rubber.
·250	·450	6·95	.. Hooper's India-rubber.
			.. Hooper's India-rubber.
..	..	1·50	Section A Hooper's India-rubber.
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..	..	8·00	,, C Hooper's India-rubber.
..	..	18·00	,, D Hooper's India-rubber.
..	..	1·50	,, A Hooper's India-rubber.
..	..	3·00	,, B Hooper's India-rubber.
..	..	8·00	,, C Hooper's India-rubber.
..	..	18·00	,, D Hooper's India-rubber.

NTION TABLE.

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or various periods t

Tem	RIFICATION (IN M							
	18	19	20	40	45	50	55	60
Fah	CE TO RESISTAN							
75°	1·327	1·33	1·333	1·365	1·371	1·376	1·381	1·384
71	1·34	1·34	1·350	1·39	1·40	..	..	..
68	1·35	1·36	1·365	1·42	1·43	..	..	..
64	1·37	1·38	1·387	1·46	1·47	..	..	..
60	1·40	1·40	1·414	1·49	1·51	..	..	..
57	1·429	1·43	1·445	1·54	1·56	..	..	..
53	1·46	1·47	1·48	1·60	1·622	1·641	1·661	1·678
50	1·50	1·51	1·525	1·66	1·69	..	..	..
46	1·55	1·56	1·58	1·74	1·779	..	..	..
42	1·62	1·64	1·65	1·87	..	..	..	..
39	1·72	1·74	1·76	2·03	..	..	..	..
35	1·88	1·905	1·92	2·22	..	..	..	..
32	2·22	2·25	2·29	2·71	2·775	2·825	2·86	2·890

NTION TABLE.

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Tem Fal	RIFICATION (IN M							
	18	19	20	40	45	50	55	60
	NCE TO RESISTAN							
75°	1·327	1·33	1·333	1·365	1·371	1·376	1·381	1·384
71	1·34	1·34	1·350	1·39	1·40	..	..	..
68	1·35	1·36	1·365	1·42	1·43	..	..	..
64	1·37	1·38	1·387	1·46	1·47	..	..	..
60	1·40	1·40	1·414	1·49	1·51	..	..	..
57	1·429	1·43	1·445	1·54	1·56	..	..	..
53	1·46	1·47	1·48	1·60	1·622	1·641	1·661	1·678
50	1·50	1·51	1·525	1·66	1·69	..	..	..
46	1·55	1·56	1·58	1·74	1·779	..	..	..
42	1·62	1·64	1·65	1·87	..	..	..	..
39	1·72	1·74	1·76	2·03	..	..	..	..
35	1·88	1·905	1·92	2·22	..	..	..	..
32	2·22	2·25	2·29	2·71	2·775	2·825	2·86	2·890

CATION TA

mith's Gutta Pe

ne minute's Electri

TRIFICATION (IN			
22	23	24	30
NCE TO RESISTA			
1·31	1·31	1·315	345
1·35	1·35	1·36	42
1·39	1·39	1·40	50
1·42	1·42	1·43	56
1·45	1·46	1·47	63
1·49	1·50	1·51	69
1·52	1·53	1·54	74
1·55	1·56	1·58	78
1·58	1·59	1·60	82
1·61	1·62	1·63	86
1·63	1·64	1·65	89
1·65	1·66	1·675	92
1·68	1·685	1·70	94

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